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THE ENGINEERS' DIGEST

REVIEW OF ENGINEERING PROGRESS ABROAD

PRINCIPAL CONTENTS

Turbine for Engine Cooling.

A Fundamental Development in Suspension and Construction for Railroad Cars.

Zero-Thrust Indicator and Elevator Locking Device : Two New Aids to Flight Measurements.

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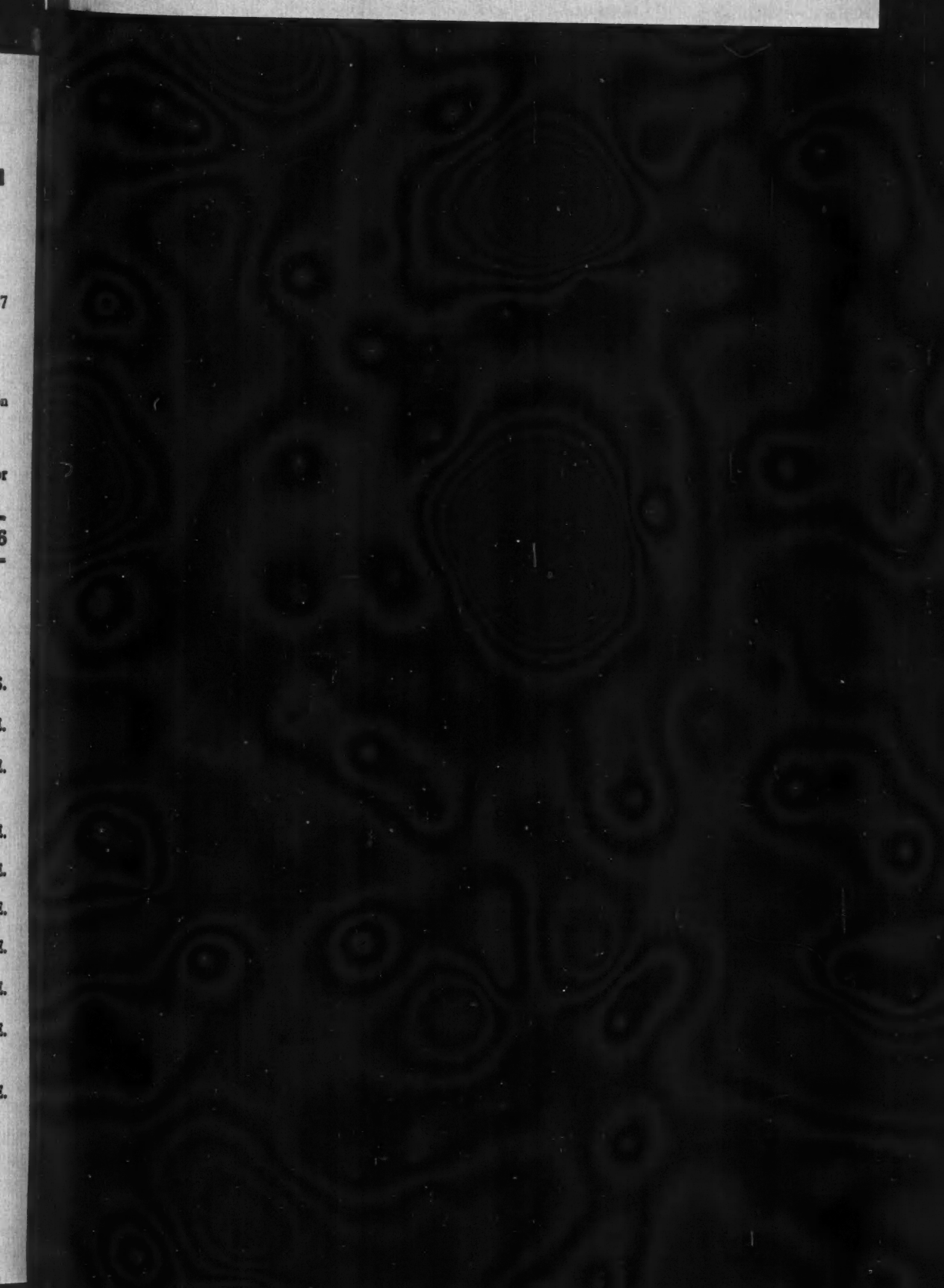

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A FUNDAMENTAL DEVELOPMENT IN SUSPENSION AND CONSTRUCTION FOR RAILROAD CARS

By P. K. BEEMER,* F. C. LINDVALL†, E. F. STONER*, and W. E. VAN DORN*. (From *Mechanical Engineering*, Vol. 62, No. 11, November, 1940, pp. 779-84.)

PASSENGER comfort at high speeds presents problems, which have thus far necessitated extensive and expensive improvements in rail and roadbed. Such changes, merely to accommodate high-speed passenger equipment with some degree of comfort, surely are not economical. The new type of truck-and-body-suspension system endeavours to solve the problem by a new design of the car.

The support of the car body on the wheels must provide adequate isolation against the vertical and lateral wheel-motions, which never can be completely eliminated, but also stability under all ordinary operating conditions. With springs having a 10-in. static deflection a high degree of comfort may be obtained. However, in conventional rail-road-truck construction, "soft" springs give to the car instability in the form of objectionable and even dangerous body roll, as they are at a considerable distance below the centre of gravity of the body. This experience in the automotive industry followed the use of springs of greater and greater static deflection. Cross-stabilizer designed to give the body freedom of vertical motion, but restricted roll, were incorporated in recent railroad trucks in an effort to control the instability of soft truck springs. But in this way the benefit of soft springs was partly lost. Lateral freedom of the suspension system is also desirable in order that the wheels may be free to follow the track irregularities without transmitting these motions to the car body.

The goal of the new development in railroad cars has been comfort at high speed on ordinary track with safety and economy of weight. The fundamental scheme has been to support the car above its centre of gravity

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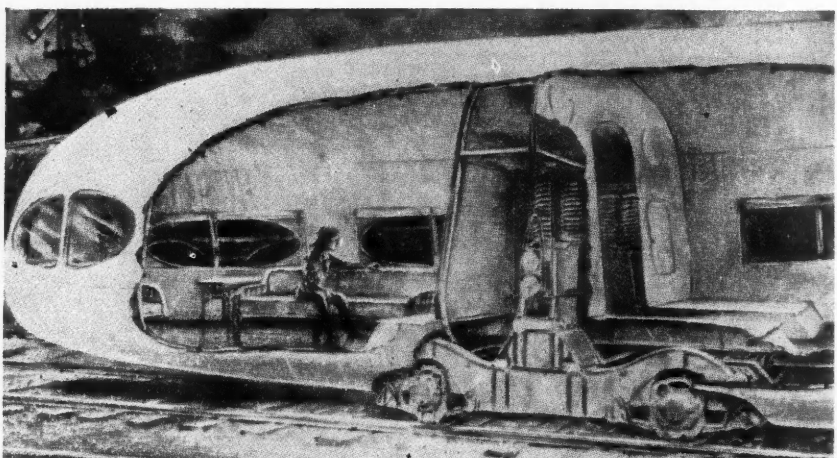


Fig. 1
Sketch of experimental car and suspension system.

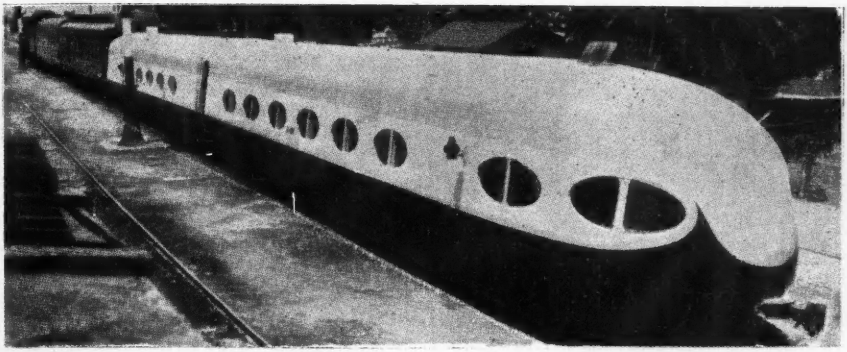


Fig. 2
Two-car experimental train unit; low floor level.

in a manner which is inherently stable. Ideally, the above gravity suspension hangs the car above its centre of gravity on an imaginary longtitudinal axis, which is allowed all necessary vertical and lateral movement against soft spring restraints. The wheels follow the rail irregularities, while the body floats about a central position. The above gravity suspension has the further advantage, that the car adjusts its position when taking curves above superelevation speeds.

First two experimental cars have been built with above gravity suspension. They are elastically supported at each end on a virtual universal centre bearing on the longitudinal centre line above the centre of gravity of the car body (Fig. 1). This virtual support permits sufficient universal swivel action of the truck relative to the car body to account for all operating conditions, and the springs, together with the positioning linkage, cooperate to achieve the desired vibration isolation. The actual car support, however, is at two points on either side of the car centre line, with a third attachment between the truck and the car body below the floor level. Consequently, no objectionable interference with the normal use of the car interior is introduced by the suspension. The desired motions are provided by flexure of the support system suitably positioned and restrained. All motions between the truck and the car body occur through elastic flexure. The practicability of the system has been demonstrated in trial runs of the two-car experimental unit (Fig. 2).

The springs, which can be seen in Figs. 1 and 3 carry only vertical load and allow, within limits of safe stress, sufficient horizontal movement of the top relative to the bottom for all lateral and turning movements of the truck in normal service. It was stated that the stresses of the springs due to these lateral deflections are not severe, and that the springs can be deflected laterally and yet be stable. Lateral movement of the car body floating on the main springs is restrained by control arms and links, which act on the body above the centre of gravity. The control arms mounted in rubber give a variable spring rate for lateral motion, so that the car floats about a centre position with small restraint, equivalent to the action of very long spring hangers, and is brought to a yielding stop for large lateral swings. The longitudinal position of the truck is maintained by the thrust tube,

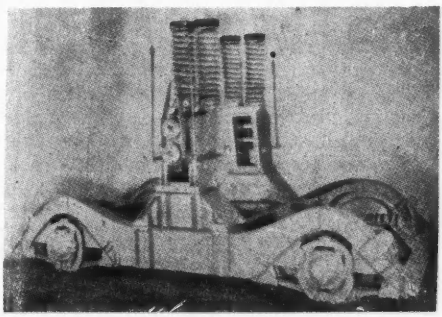


Fig. 3
Truck for experimental car.

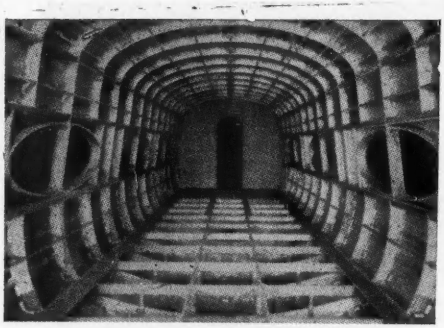


Fig. 4
Reinforcing rings and longitudinal stiffeners as applied to plywood skin of experimental cars.

which is anchored in rubber at one end of the truck frame and at the other to the car underframe. The rubber mountings of the longitudinal tie permit lateral movement of the truck and angularity on curves as well as constituting barriers against noise transmission.

The car bodies of the test unit were, for reason of simplicity, fabricated of plywood into stressed-skin structures. High strength and rigidity were thus obtained at minimum weight. Moreover, most of the usual auxiliary equipment of passenger cars was omitted from these units so that the two-car articulated unit 145 ft. in length weighed only 33 tons on the rail. The cars underwent an extensive road-test program, which showed that nearly no modifications were desirable. The trucks were tried with conical and with cylindrical treads. In neither case they were subjected to " nosing," that is, wandering continuously from one side of the track to the other as permitted by the necessary flange clearing and lateral rail flexure. Despite their extreme light weight these cars in road tests, at speeds up to 100 m.p.h., demonstrated outstandingly better riding quality than older heavy-weight equipment and modern light-weight coaches utilizing conventional trucks.

Based upon the success of the experimental train unit, the Santa Fe, the Great Northen and the Burlington Road, each contracted for a de-luxe type coach, incorporating the above gravity suspension system and skin-stressed light-weight body structure. The three railroads have agreed for a test period, to keep the three cars together in road service, in order that the middle car of the group functions in a representative manner. But the cars have to be built for unrestricted interchange service with standard equipment.

The greater weight of these cars necessitated the use of eight body springs per truck. The static deflection of 10 in. together with the rubber insulator on the top of the spring with a deflection of $\frac{3}{4}$ in. provide highly satisfactory isolation of the body from disturbances in the truck. The lateral springs are two plates clamped rigidly to the side of the truck frame, extending to a point above the centre of gravity of the body. They are attached to the car body with rubber-mounted end connections.

The bodies of the cars will be steel-stressed-skin structures, the skin being a load-carrying element, as has been used for a long time with structures of aircraft and during the last years with buses and large-sized trucks and trailer bodies. Good appearance and reduced air resistance are inherent in a stressed-skin car. Fig. 4 shows the interior of the experimental car, Fig. 5 the steel roof of the cars ordered by the railway companies. The flooring is shear-connected into the structure, making the car body a huge tube closed at both ends, with a high degree of bending and torsional rigidity. Eliptical windows in-

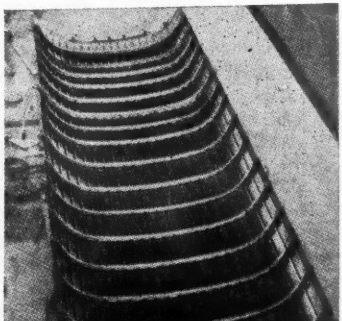


Fig. 5 Steel-roof-panel assembly.

crease the rigidity of the body. The cars have very high end—and side—collision strength. The entire body, excluding certain arc-welded, end-framing and draft-gear attachments, is fabricated with spot-welding. A special welding machine is used, which combines welding and handling the parts of the skin of the cars. Electronic time control provides consistent spot welds having high strength.

DIFFUSION IN ALPHA SOLID SOLUTIONS OF ALUMINIUM

By R. F. MEHL, F. N. RHINES and K. A. VON DEN STEINEN. (From *Metals and Alloys*, Vol. 13, No. 1, January, 1941, pages 41-44.)

MEASUREMENTS of the rates of diffusion of a number of elements in aluminium have been made by many authorities, whose results are assembled in Fig. 1. These values show the variation of the diffusion rate with temperature, but not with alloy concentration. Since in some cases the diffusion coefficient is changed as much by a variation of one per cent in concentration as by a variation of 50 deg. in temperature, it is evident that the effect of concentration is an important one.

The present research has been designed to determine the variation of the diffusion coefficient with alloy concentration as well as with temperature in the aluminium-rich solid solutions in the systems Al-Cu, Al-Mg, Al-Si, Al-Ag, and Al-Zn. A summary of the results is shown in Fig. 1, where the shaded areas denote the range of values of the diffusion coefficient between the concentration limits specified.

Many of the previously published values fall within the shaded areas of Fig. 1, suggesting that the differences among the various investigators have not always been the result of errors of measurement, but may sometimes have been caused by a difference in the alloy concentration with which each value is to be associated. Where experimental errors have occurred their source lies most commonly in the presence of a film of aluminium oxide between the two parts of the diffusion couple, for aluminium oxide is capable of interfering with diffusion and its presence may lead to low values for the diffusion coefficient.

Sheets of pure aluminum, 0.375 in. thick, rolled from a commerc al 7 in. × 14 in. × 28 in. ingot were annealed for two hours at 413 deg. C. Alloys, Table 1, made from pure aluminium were melted in plumbago crucibles and cast as ingots 1.5 in. × 8 in. × 7 in., weighing 8 lbs. each. These were taken from the mold hot, placed between pure aluminium slabs, cooled to 455 deg. C., and reduced 0.125 in. in thickness by rolling to produce a bond. The silver alloys were made in 4 lb. ingots. To promote homogenization, the copper, magnesium, and silicon slabs were then heated for 12 hrs. at 477° C., of which time about 5 hrs. was required to reach the specified temperature. The silver and zinc alloys were heated for a similar time at 385° C. Upon removal from the furnace, the slabs were cooled to a suitable working temperature and rolled to a thickness of 0.375 in., the copper,

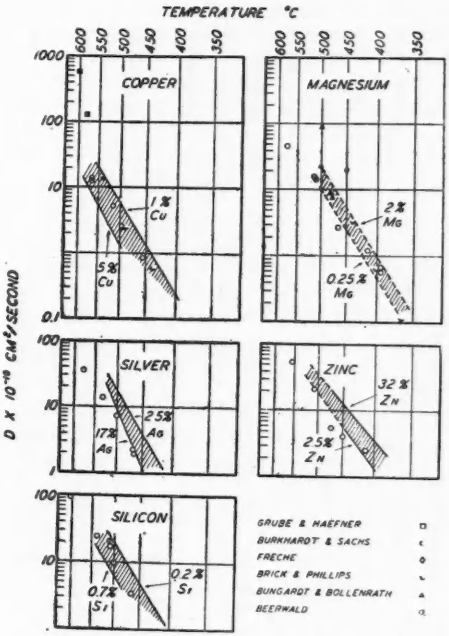


Fig. 1.

magnesium, and silicon alloys being rolled at 455° C. and the silver and zinc alloys at 315° C.

From the most perfect section of each finished sheet, strips $\frac{1}{2}$ in. × 6 in. were cut for the diffusion studies. Samples of each alloy were heated in duplicate for 100 hrs. at 400° C., 450° C. and 500° C.

For chemical analysis layers 0.005 in. thick were cut with a shaper parallel to the interface between the coat and core of the sample, the location of which was determined by etching the edges of the sample to reveal the junction. In all, 10 layers and the core material were analyzed for each sample.

For the spectrographic analyses the samples were cut in a series of steps, each 0.005 in. deeper than the next, and the test spark was located in he centre of each step. A number of readings were averaged to obtain values for the computation of the diffusion coefficient.

Calculating the diffusion coefficient, a definite amount of preliminary diffusion was taken into account; the amount of this preliminary diffusion was determined by analyzing "blank" samples that had no heat treatment subsequent to fabrication.

In order to compensate for diffusion during fabrication a simple modification in the computation is required. The diffusion coefficient is computed in the usual way except that the time of diffusion is taken as the sum of the experimental time noted and an unknown value t corresponding to the time equivalent of the diffusion during fabrication. The diffusion coefficient is simultaneously computed from the blank sample in terms of the unknown time t. This gives two simultaneous equations with two unknowns, t, and the diffusion coefficient, D, and from which the value of the latter is obtained by substitution.

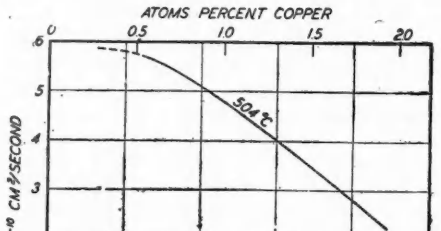


Fig. 2.
Variation of the diffusion co-efficient in aluminium-copper alloys.

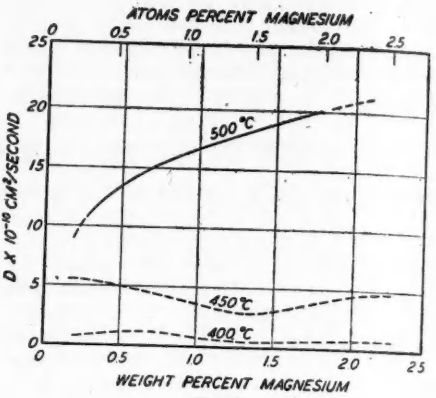


Fig. 3.
Variation of the diffusion co-efficient in aluminium-magnesium alloys.

The results are shown in Figs. 2 to 6. The largest errors introduced in the determination of diffusion coefficients is by (1) inaccuracy in chemical analysis (2) uncertainty in the temperature of diffusion, and (3) uncertainty in the measurement of the slopes of the penetration curves. The chemical analyses may be regarded as accurate to within $\pm$ 0.08% at low concentrations and 0.3% at high concentrations for the alloys containing Cu, Ag, and Zn. The spark spectrographic method was used for the Mg and Si analyses.

All heat treatments were carried out in a temperature controlled muffle furnace equipped with a heavy aluminum block that limited the temperature range to $\pm$ 1° C. Errors in the measurement of the slopes of the penetration curves are greatest near the zero and maximum concentration limits and, consequently, results have not been reported for concentrations in these ranges.

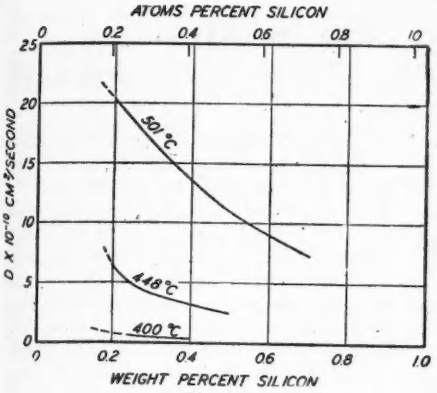


Fig. 4.

Variation of the diffusion co-efficient in aliminium-silicon alloys.

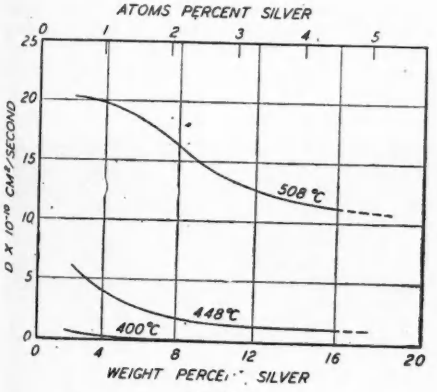


Fig. 5.

Variation of the diffusion co-efficient in aluminium-silver alloys.

We may note that the diffusion coefficient increases with increasing solute concentration when the solute is low-melting, and decreases with solute concentration when the solute is high-melting. Other relationships may be noted: The diffusion coeff. appear to approach a common value of $20\text{-}25 \times 10^{-10}$ sq. cm. per sec. at 500° C. in the system with Si, Ag, and Zn, and a value 6.10^{-10} sq. cm. per sec .in the systems with Cu and Mg.

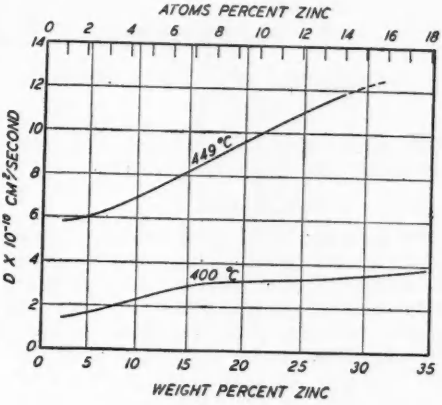


Fig. 6.

Variation of the diffusion co-efficient in aluminium-zinc alloys.

The precision of the measurements does not warrant a calculation of the activation heat of diffusion Q as a function of concentration; an average value may be obtained by drawing straight lines with slopes intermediate between the two extremes of the shaded areas in Fig. 1. These values are l sted in Table II.

TABLE I.

Alloy No.	Si	Fe	Cu	Mg	Ag	Zn
100, 200, 300	0.01	0.01	6.96	—	—	—
1,600	0.01	0.01	0.01	2.49	—	—
1,800	2.54	0.01	0.01	—	—	—
1,900	0.01	0.01	0.02	—	10.28	—
2,000	0.01	0.01	0.03	—	19.82	—
2,100	0.01	0.01	0.01	—	—	20.18
2,200	0.01	0.01	0.01	—	—	40.02
Surface layers	0.01	0.03	0.01	—	—	—

TABLE II.

Diffusing Metal	Intermediate value of Q cal. per gm. mol.
Cu	33.900
Mg	32.200
Si	31.500
Ag	38.500
Zn	25.800

"CERBERUS" ALARMS AND SIGNALS

By W. JAEGER, Maienfeld. (From *Schweizerische Bauzeitung*, Vol. 116, No. 22, 30th November, 1940, pp. 247-50).

THE article gives a description of a new fire alarm and a new burglar alarm.

FIRE ALARM.

A fire alarm has to be released by changes, which are brought on by combustion. There is always a production of heat connected with combustion, frequently of light and smoke, too. But the alarm cannot be based on the production of heat, as with a small fire the rise of temperature may only be sufficient near the fire. In a greater distance the rise of temperature may not be greater than changes caused by heating, sunshine, etc.

Many older alarm-systems used the visible smoke as a criterion of a fire. But combustion must not be associated with smoke; moreover, these installations are rather expensive, and need continual attendance.

Now a new system of fire alarm has been developed, which depends neither on the temperature of the air nor on the presence of smoke, but works as soon as there is a smell of burning. The new instrument is based on a control of the air in regard of complexes of molecules by radium radiation. Besides it uses a new instrument, the potential relay.

By the heat, which is produced by a combustion, parts of the burning body (salts) are vaporised and become charged with electricity (ions). These charged particles give rise to the formation of complexes (Langevin-complexes), some millions of molecules clinging on them. An arrangement according to Fig. 1 can be used in order to ascertain if the air contains such complexes. The air to be tested is brought in the ionisation chamber 2. It becomes ionised by the α—particles emitted by the radioactive matter 4, some molecules being split into electropositive and electronegative particles (ions). The positive ions are attracted by the electrode 5', the negative by the electrode 5, where they discharge. This makes a current flow through the resistance 1. The voltage at its ends is measured with the electrometer (E) by the motion of its vanes. It has been found that a high increase of current occurs when the air in the ionisation chamber contains flame-gases or smoke, or when the air is only taken from near a combustion or a glowing body. Such increases of the current occur even if the air does not contain any visible smoke. It was stated that changes of the chemical composition of the air have not so great an influence on the behaviour of the apparatus. Therefore, it is very suitable to be used as a

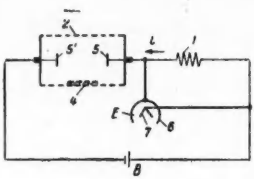


Fig. 1
Diagram
of connections.

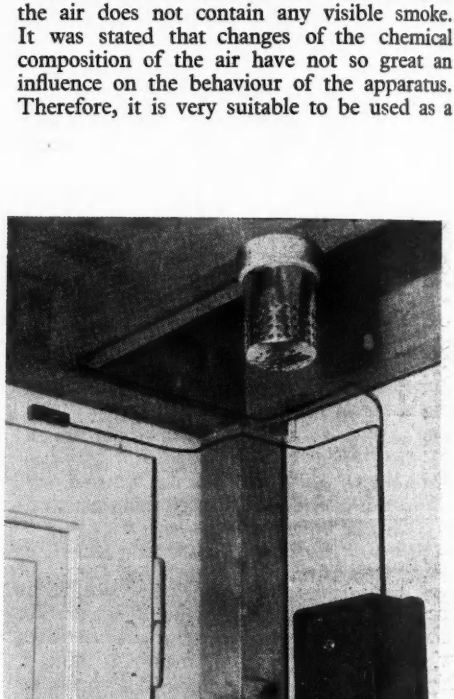


Fig. 2
"Cerberus" Fire and Burglar Alarm with Alarm Signal.

fire alarm, in the manner shown in Fig. 3*.

In the ionisation-chamber (2) the air of the room is controlled continuously, being ionised by the radioactive film (4), which is protected by a metallic coating (5). The resistance (1) of Fig. 1 is replaced by a closed ionisation-chamber, which contains the radioactive layer (3). When the electrometer vanes (7) become charged and open, they initiate a gaseous discharge between the contact electrode (8) and the movable electrode (7). The heater winding (10), with the protective coating (9) has to maintain perfect insulation. Fig. 2 shows the little apparatus on the ceiling of the room to be protected.

The air is controlled continuously as it enters and leaves the ionisation-chamber by diffusion and convection. As the apparatus contains no wearing parts its life is practically unlimited. The same wire can be used for connecting many alarms with the common fire bell or with several fire bells.

The new fire alarm is so sensitive that it functions even at the smallest fire†. A little smouldering cotton waste, which produces only smoke, but no flame, or an ounce of burning wood wool, or some pieces of newspaper, which burn without producing smoke, cause the alarm to be given at once in a middle-sized room. One can choose the sensitivity of the alarm according to the circumstances prevailing. Generally it is adjusted so that

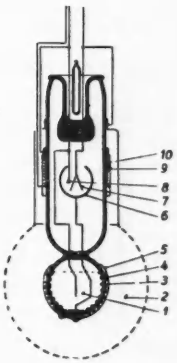


Fig. 3
Diagrammatic sectional drawing of a fire alarm.

no alarm is sounded from a middle-sized room in consequence of the smoke of a few cigarettes or a cigar, but by every larger combustion. As the air rises from the point of the combustion, the best place for the fire alarm is near the ceiling. Even a very large room can be perfectly protected by only a few apparatuses. The alarm can be combined with any optical or acoustical signal.

BURGLAR ALARM.

The burglar alarm has to function at any attempt of burglary, i.e., it has to give a signal when windows or doors, etc., are opened by force. When placed in the soil it may even give an alarm at normal steps. The shakings produced, propagate as vibrations through the matter, and through the air as sound. Fig. 4 shows the chart produced by the vibrations emanating from a shock in a distance of about 3m. from the recording apparatus. A step had

* For a more detailed explanation of the working of the apparatus refer to W. Jaeger, Die Ionisationskammer als Feuermelder, Bull. S.E.V., Vol. 31, No. 9, May, 1940, p. 197/200.

† W. Jaeger, Selbsttätige Feuermeldung mit Radiumstrahlen, Mitteilungen d. Ver. Kant. Schweizer Feuerversicherungsanstalten, Vol. 19, No. 2, 1940, p. 73/84.

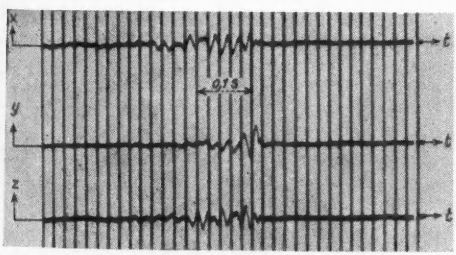


Fig. 4
Seismogram of a step.

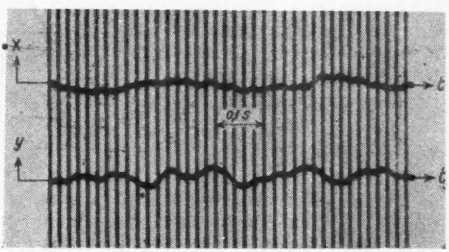


Fig. 5
Seismogram of a train passing at approximately 50 m. distance.

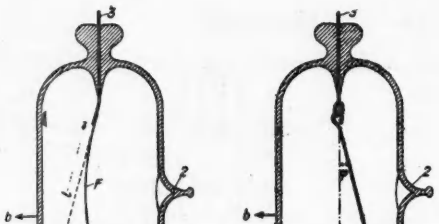


Fig. 6

Diagrammatic drawings of acceleration contacts: (a) Spring contact; (b) Pendulum contact.

been chosen as an example of a shock. The vertical lines are time marks in intervals of 0.02 sec. Fig. 5 is the diagram produced at the same place as Fig. 4 by a train passing at a greater distance. The essential difference between these diagrams is that in the diagram of the train there are no high frequency vibrations, which die away during the longer transmission through the soil, although, of course, the impluse given by the train is stronger than that of the step. Now the high frequency vibrations as produced by the step have a higher maximum acceleration than the low frequency vibrations transmitted by the train or other similar shaking. This difference is independent of the amplitudes of the vibrations. A burglar alarm, which has to function at disturbances originating in its neighbourhood, has to be constructed so that it responds to the maximum acceleration of the vibrations, and not to their amplitude.

The new type of alarm as shown by Figs. 6a and 6b, fulfils this condition. An acceleration of the apparatus in the direction of the arrow, which exceeds a certain limit—this limit depends on the mass of the little sphere (m) and other details of the apparatus—will

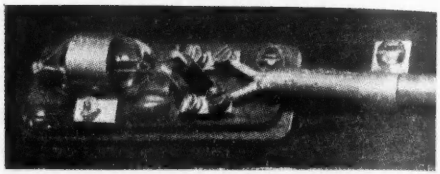


Fig. 7

" Cerberus " Burglar Alarm for protecting windows and doors.

have the effect, that the contact between s and r is opened and the circuit is interrupted between 3 and 4. This interruption initiates the signal. In order to secure a reliable contact, even with very little pressure between the contacting points, the apparatus is sealed in a glass vessel. By using a suitable gas for filling the vessel and with the correct special metal for the contacts, they conserve highest sensitivity, and sticking of the contacts does not occur.

The original publication deals in detail with the interesting molecular phenomena, on which the behaviour of the contacts depends. It is possible to give the alarm the right range of sensitivity, according to its destination. The apparatus, which have to guard windows or doors, have to respond to accelerations of 500 to 1000 cm. sec. $^{-2}$, whereas for protecting rooms against unauthorised persons an acceleration of 50 to 100 cm. sec. $^{-2}$ must release the alarm. Fig. 7 shows an alarm for the protection of windows or doors. Such an alarm can be seen above the door in Fig. 2 too. When used for protecting wire-trellis or railings the alarm is enclosed in an iron box, which is filled with a compound (Fig. 8).

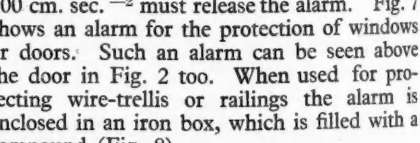


Fig. 8

" Cerberus " Burglar Alarm for protecting wire-trellis or railings.

A NEW RADIO AID TO AIR NAVIGATION

By DAVID G. C. LUCK. (From *Aero Digest*, Vol. 38, No. 1, January, 1941, pp. 49-56).

RADIO aids to air navigation take three forms. The aircraft direction-finder shows the direction from which radio waves reach the airplane. The ground direction-finder shows the direction from which radio waves from a plane reach a fixed ground point. Finally, there is the radio range beacon on the ground, which sends out radio waves of distinct characters in definite directions.

Radio compasses are fine for homing, headed always directly at a transmitter. But to find out where you are or to follow a straight course home, you must correlate their readings with magnitic compass headings, and make some computations.

Ground direction-finders work in groups so that a pilot need only radio the question, "Where am I?" Hence a pilot dependent upon ground direction-finders must reveal his position to all in order to learn it himself. Further, only one airplane can be served at a time by a ground direction-finding group.

Since all radio guidance can be disrupted by sufficiently bad interference, everyone is looking hopefully toward the use of ultra-high radio frequencies, on which the interference problem is tremendously simplified by the almost complete absence of natural static. Just now, there seems no hope of a fully satisfactory ultra-high frequency radio compass. Ultra-high frequency ranges, on the other hand, are already in successful operation.

The subject of this article is an improved form of ultra-high frequency range that is as flexible and convenient to use as its new alternatives, and is not limited to a few fixed, indirectly distinguishable courses. Because it, in effect, marks out a fixed course wherever one is wanted, and marks as many of them at once as wanted, it is called an "omnidirectional radio range."

Azimuth Indicator and its Use.

It consists of a standard A-N size face in the instrument panel, and, as shown in Fig. 1, the bright circle with the marking jog appears in green light against a dark background, the position of the jog being read against a 0° to 360° azimuth scale. The jog points out, definitely and automatically, the line of position, from the range beacon tuned in, of the receiving ship.

This instrument is a true indicator and its reading does not depend on the heading of the receiving ship. Suppose a pilot, getting a 240° reading from Philadelphia tunes over to a range at York, Pa., and reads a bearing of 120°. He may transfer both readings directly to his map with a protractor, and locate himself at their intersection. Where two omnidirectional ranges can be heard a complete radio position fix may be thus obtained.

If the pilot wants to keep a straight line course, he need only hold his omnidirectional range azimuth reading constant. In a cross-

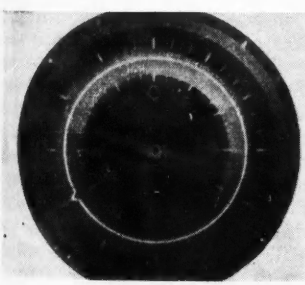


Fig. 1.

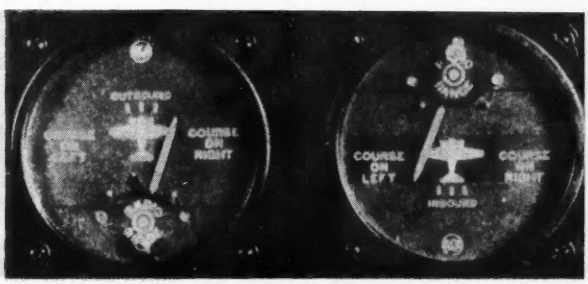


Fig. 2.

wind he will merely find his compass heading crobbed away from his range bearing. When he enters the cone of silence over the Philadelphia range, the bright circle will begin to jump, and then will collapse, while still indicating the same reading, e.g., 240°. The circle, still jumpy, re-appears reading 60° as he emerges from the far side of the cone, after passing over the range. Thus he gets a striking and positive cone of silence indication. Should he miss the cone slightly, the circle will not collapse, but the jog will run rapidly halfway around it as he passes the range, always indicating the bearing of his airplane from the range, and so showing on which side of it he has passed.

It should be remembered that inbound the pilot must veer to the right to decrease his bearing, or to the left to increase it. Outbound, these rules are reversed. The range does not tell whether a ship is outbound or inbound without manœuvring. The magnetic compass supplies that information. If compass card and range indicator read alike, the course is outbound, if they read reciprocally, the course in inbound.

Deviation Indicator and its Use.

Intuitive application of the rules for right and left bearing requires considerable practice. Concentration of the full 360° in a small scale makes slight bearing changes inconspicuous. Therefore, for the pilot's convenience a zero centre pointer instrument is provided, which gives magnified and correctly-sensed indications of small deviations from a chosen course.

To use this a course-setting control knob is turned to read the bearing from a range of a desired radial course. The pilot then flies to intersect that course. When appearance of the desired reading on the azimuth indicator shows that he is on his chosen course he trims the knob setting to centre the deviation indicator, and turns to head along that course. The deviation indicator Fig. 2 thereafter shows direction and amount of lateral drift.

The deviation indicator needle swings across the small pictured airplane, just as the real course swings across the real airplane when there is a drift. Far from the range, a given change of bearing corresponds to a large change of position, while close in the same bearing change is accomplished in a small distance. While the deviation indicator may be used directly as a flight instrument when close to a range, it is too sluggish farther away, where it serves preferably to establish the compass heading to be held to keep on course. The right heading can be found with bracketing, as with present ranges. But his flying is neater and needs fewer trial headings in bracketing, if he starts, outbound with a time heading accurately equal—or reciprocal, if he is inbound—to the indicated true bearing, and corrects it for known cross-wind.

How the Range Beacon Works.

The omnidirectional radio range beacon is a radio light-house, which sends out a beam rotating at uniform speed. The light-house beam is so broad as to be always "visible" in all directions, and goes out entirely, for an instant, just as its maximum intensity points due North. In any particular direction from the beacon the result is a radio signal, whose strength varies smoothly between a lower and an upper limit, the latter reached just as the beam sweeps by and drops briefly and sharply to zero each time the beam points North. In different directions the time interval between each maximum signal, from the continually sweeping beam and the next following North-marking blink, is different. With counter clockwise beam rotation, this interval increases steadily from zero to the full period between successive marking blinks as the azimuth of observation increases, clockwise, from 0° to 360°.

The rotating beam is obtained by varying the relative radio power fed to 5 fixed antennas, located at the corners and centre of a square, having its diagonals pointing North-South and East-West. The central antenna sends out a steady signal which has the same strength in every direction. The North and South antennas together send out a fixed double beam, with maximum strength to Northward and Southward, falling off smoothly to no signal Eastward and Westward. The Northward beam adds to the signal from the centre antenna, while the Southward beam subtracts from it. Thus a broad fixed beam is produced, with intensity varying smoothly with azimuth from a single maximum pointing

North to a single minimum pointing South. Reversing the connections to the North and South corner antennas reverses the resultant beam, causing the maximum to point South. The East and West corner antennas alone produce an East-West double beam. This combines with the non-directional signal of the centre antenna to give a single beam with maximum pointing East or West, according to the polarity of the connection to the corner antennas. Switching power cyclically between the corner antennas with alternating polarities, thus results a single beam with maximum successively pointing North, West, South, East, etc. Just as the East-West double beam component falls to zero strength the whole signal to all antennas is abruptly cut off for an instant. This instant is just that at which the resultant single beam has its maximum due North. As all functions are performed electrically there is no speed limit, and the beam is actually swept around 60 times a sec., each blink lasting about 1/10000 sec.

How the Azimuth Indicator Works.

The azimuth indicator times the interval between the maximum of the smooth radio signal variation and the sudden loss of signal. For this purpose an index is moved steadily around a circular scale by the smooth variation of signal. The index is moving in step with the beam. The sudden drop is made to kick that index momentarily out of its circular path.

On the airplane a normal receiving antenna picks up the signal. A radio receiver equalizes strong and weak signals in a faithful reproduction of the rapid incoming signal variation. The indicating equipment is plugged into a headphone jack and works on the output current variation only. From the general mixture of noise the smooth beam rotation variation and the sharp North-marking variation are separated out into two different circuits by means of electrical wave filters. Part of the periodic variation wave is used directly; part of it delayed, before use, in an electrical circuit, so that every part of the resulting wave occurs a quarter of the wave period later than the same part of the original wave.

In a cathode-ray tube, a narrow stream of electrons shot out of a "gun" is arranged to move up and down in step with a voltage applied to one pair of tube terminals, and from side to side in step with the voltage on another pair of terminals. Wherever the electron beam hits a fluorescent screen on the flat end of the tube opposite the gun a bright spot of light appears. The direct wave from the filter produces a vertical movement, and the delayed wave produces a horizontal movement of the light spot, thus resulting that the spot moves steadily clockwise in a circle in step with the transmitter beam rotation so fast that it appears drawn out into a smooth circle of light. The spot is at the top of its circle as the beam maximum points at the receiving craft, and the azimuth scale applied to the face of the tube is so adjusted that the spot arrives at scale zero exactly at the passage of the beam maximum.

Sharp North-marking signals, separated from the receiver output by their high pass filter, are used to reduce the accelerating voltage on the gun. These signals thus swerve the spot briefly outward from its path to mark a jog on the circle of light. When the transmitted beam has moved through the azimuth angle of the ship, it points North and winks out, kicking the indicator spot, which has moved through the same azimuth angle outward and so marking a bright jog against the indicator scale at that angle.

Operation of Deviation Indicator.

The deviation indicator shows the amount and direction of any change of the interval from beam maximum to North-marking, from a chosen amount. For this purpose an electric circuit giving a time delay of the waves passing through it, which can be varied over the whole beam rotation period by turning a control knob, is fed from the filter segregating the beam rotation wave. Part of the output is used directly and part is further delayed by $\frac{1}{2}$ period, providing two voltages that vary in exactly opposite fashion. Each of these tend to deflect the meter needle in one direction, and the two deflecting effects are opposed.

North-marking signals close a vacuum tube switch, normally open, and permit the

opposing voltages to act briefly on the meter, once during each beam rotation. If the adjustable delay has been so set that, with the receiver in a chosen azimuth, the oppositely varying voltages become equal at the marking signal — the momentarily applied forces balance and the needle stays centred while the receiver remains in the azimuth.

If the bearing decreases, the beam arrives later to the receiver, the North-marking comes sooner after the beam maximum, the two voltages have not reached equality, and the meter deflects in one direction. The needle is deflected in the other direction, if the bearing is increasing. The sluggish meter averages out the kicks received, and shows thus a steady deflection. Full deflection can be obtained on the meter with small deviations.

Experimental Results.

An experimental omnidirectional range beacon was set up at Central Airport Camden, N.J., and flight-tested with a receiver and indicators set up in a transport airplane. The apparatus development was continued until overall ground calibration at short distances from the antennas gave no error in indicated bearing of more than 3°. The average error of the automatic, direct azimuth indications at 24 ground calibration points was then about $\pm$ $^2/_3$°.

Flight calibrations were made, the results being shown in Fig. 3, the dots representing readings at points about 10 miles out and the open circles readings at points about 25 miles from the range. Errors considerably greater than those due to equipment are quite evident. Despite some scatter, a trend is evident, indications being high in South-Easterly and low in South-Westerly directions. This trend is probably caused by obstacles near the beacon antennas. The overall average errors observed were about $\pm$ 3.5°, never exceeding 10°.

On the cathode-ray azimuth indicator noise not greatly in excess of the signal appears only as extra dancing jogs on the bright circle. The judgment of the pilot can, however, readily separate these from the steady jog giving the real reading.

At the ultra-high frequency, bearings observed in flight were generally somewhat unsteady. Efforts to improve this condition in the experimental Ford trimotor, were only successful up to a certain limit. A flight in a small dirigible for the study of causes of unsteadiness, showed that thoroughly stable ultra-high frequency bearing indication is possible in an aircraft in flight. The difficulties indicate, however, that much care must be given to minimizing extraneous effects, such as disturbance of the signal by spinning propellers, noise from electrical equipment, imperfect structural boundings, etc.

The means provided in the transmitter to enable the ground operator to check at a glance the accuracy of the bearings being sent out have proved satisfactory. Bearings indicated are truly independent of heading and attitude, as they should be. However, when in manœuvring a banked wing, or the fuselage lies directly in the path of the ultra-high frequency waves to the antenna, the signal is temporarily weakened greatly or lost. Course bends or multiples are present to just the same extent as with any range operating in the same location and on the same frequency. The apparatus behaviours during tests seem to imply an entirely practical degree of stability of such equipment.

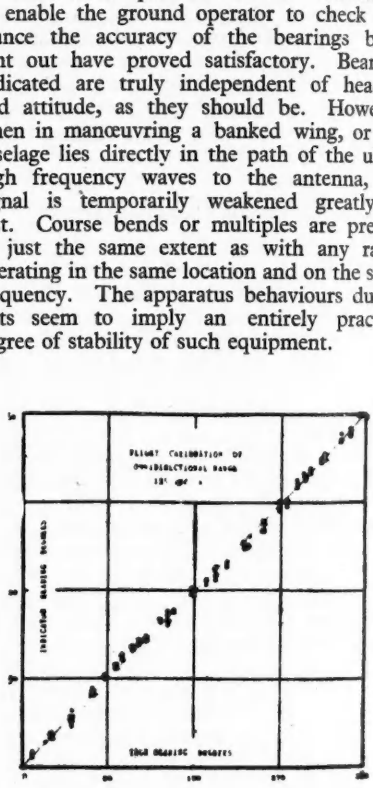


Fig. 3.
Results of flight calibrations.

VARIATION OF THE TENSILE STRENGTH OF CAST IRON WITH TEMPERATURE

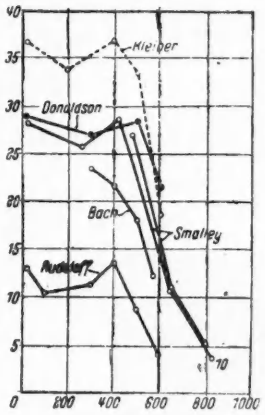
By DR. F. ROLL. (From *Die Giesserei*, Vol. 27, No. 7, April 5th, 1940, pp. 123-124).

THE behaviour of the strength characteristics of cast iron with variation of temperature has been established already. It was found from these experiments (Fig. 1) that with increasing temperature, a decrease of strength takes place which is followed by a rise at about 250° C. The same results were obtained from experiments on steel.

The consideration of the composition of iron, i.e., the silica, chromium, nickel, etc., content does not give a satisfactory explanation to this phenomena. Neither does the theory of magnetic change of the iron carbides (Curie point).

The strength-temperature curve of cast iron shows a rapid fall after reaching a peak value, according to the literature regarding this question. No further examination of this part of the curve was carried out.

It was found, however, that in the (A_1-A_3) transformation range the process of corrosion was unsteady, and at the same time the strength curve underwent a change of direction, as was found from experiments on iron and sulphur. Hence it was expected that also in the case of cast iron a change in strength characteristics will be experienced above 700° C. This question was investigated and the results are given below :



Temperature °C.

Fig. 1.

Experiment No. 1. Pearlitic cast iron with an initial strength of 26.5 kg/mm² was examined. A kink was found on the strength-temperature graph between 725° and 735° C. The following arrangement was used to measure the strength of the sample : a thermo-element made from platinum-platinumrhodium was fixed on to the test sample by a 1 mm. dia. copper wire, and was protected by a thin mica sheet from direct heat radiation. A second mica sheet protected the thermo-element along the entire effective length from radiation of heat from the outside. (See Fig. 2).

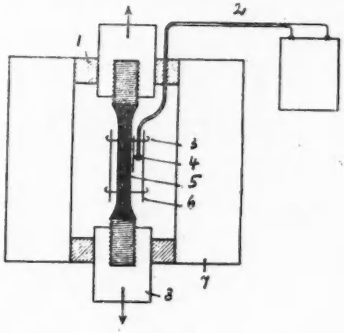


Fig. 2.

1, Asbestos. 2, Thermo-couple. 3, Copper Wire. 4, Thermo-couple. 5, Cast-iron rod. 6, Mica. 7. Platinum coil furnace. 8, Cover.

The cast iron sample of 10 mm. effective length, was screwed into the furnace covers (screw threads being cut on the sample for this purpose) and was heated to the appropriate temperature. No load was put on it for twenty minutes, after which it was tested in the usual manner. The results are shown in Fig. 3, the strength figures referring to the cross sections corresponding to braking conditions. It can be seen from the curve that the strength first decreases until about 600° C, and forms a kink at about 700°-730° C, after which it falls first rapidly, then more slowly.

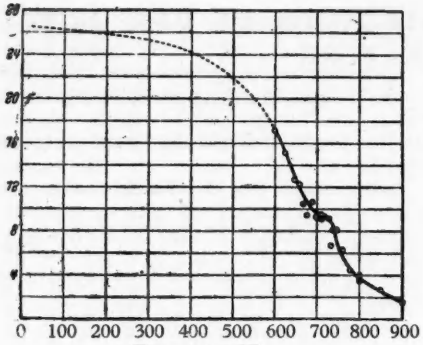


Fig. 3.

Experiment No. 2. The same result was obtained with cast iron of initial strength of 32.5 kg/mm². The kink started at about 750° C, and lasted until about 850° C was reached. (See Fig. 4). The variation of elongation with temperature is shown in Fig. 5.

It can be concluded that an unstable condition exists in the A_1-A_3 region, which can be contributed to reactions of inter-crystalline rearrangement.

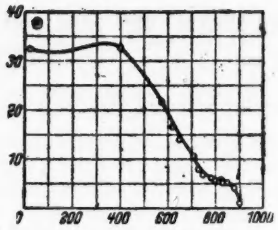


Fig. 4.

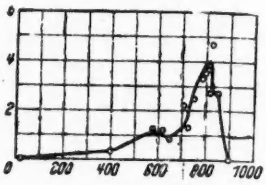


Fig. 5.

THE INFLUENCE OF PITCH ANGLE OF MILLING CUTTERS

By M. GEYER. (From *Werkstatt und Betrieb*, Vol. 73, No. 4, April, 1940, pp. 76-77).

THREE milling cutters, with pitch angles of 30°, 45°, and 70° respectively, were examined for output, quality, finishing, cutting value, and economy. During cutting a maximum and a minimum cutting force is present. The ratio of the two, i.e., min. cutting force/max. cutting force, is the co-efficient of cyclic variation, and is itself a measure of the quality of the finished surface. Cutters with straight toothing operate irregularly and impulsively, while cutters with twist toothing show a more or less uniformity in operation depending on the angle of pitch.

The cutters tested are shown in Figs. 1 to 9. The particulars of the cutters are as follows :

λ	d.	b.	B.	Z.	γN.	α N.
30°	90	150	40	9	28°	4°
45°	90	150	40	5	26°	5°
70°	90	150	40	3	24°	6°

where d. = diam. in mm., b. = width in mm., λ = bore of cutter in mm., Z. = no. of teeth, L. = pitch angle, γ N. = standard cutting angle, and α N. = standard free angle. The standard angles are those measured perpendicularly from the cutting edge.

For the purpose of test a Wanderer-Konsol milling machine was used, and the light load power taken by the machine was deducted from the total power used for cutting when calculating the efficiency of the tools.

The work consisted of cast iron blocks, with Brinell hardness of 180 kg./mm², and steel of 55 kg./mm² strength.

Small cutting speeds with large advances were arranged,

No. of revs. = 52
cutting speed = 14.7 m./min.
feed = 440 mm./min. = 8.46 mm./rev.

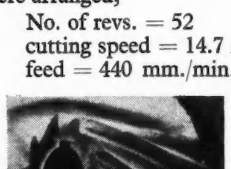


Fig. 1.
Milling Cutter with Pitch Angle of 30°.

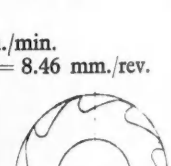


Fig. 7.
Frontal surface.

Fig. 2.
Milling Cutter with Pitch Angle of 45°.

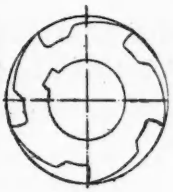


Fig. 8.
Frontal surface.

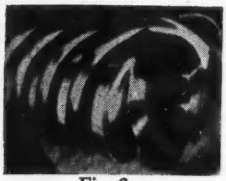


Fig. 3.
Milling Cutter with Pitch Angle of 70°.

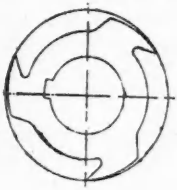


Fig. 9.
Frontal surface.

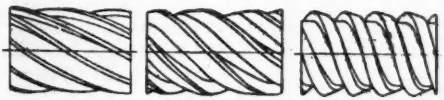


Fig. 4. Fig. 5. Fig. 6.
Sketch of the Milling Cutters with Pitch Angle of
30° 45° 70°.

Feed with $\lambda = 30° = 0.94$ mm./tooth
" " $= 45° = 1.69$ mm./tooth
" " $= 70° = 2.82$ mm./tooth
Conditions were identically arranged.

The axial forces were taken by the table guides and spindle bearings. With shank end mills the pitch angle is so arranged that the axial pressure is taken up by the cutter spindle bearing. The axial pressure is eliminated when two spindles are used with opposing pitch angles.

It can be seen from the graph that the efficiency is increasing with decreasing value of the pitch angle.

Fig. 10 shows the curves for specific efficiency, i.e., the quantity of chip discharged/min. when the power consumption is 1 KW. The maximum specific efficiency is naturally a measure of the cutter economy. In estimating the efficiency of the tool, other factors as well have to be considered, such as rigidity of the work, strength of the work, cutting depth and cross sectional area.

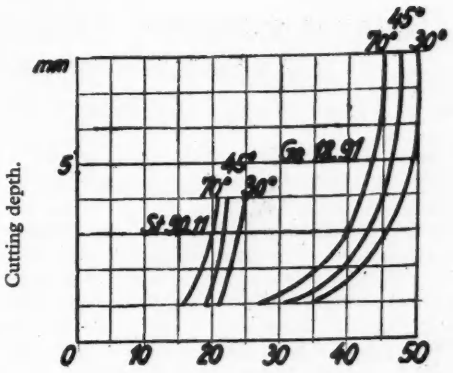


Fig. 10.

The best performance was obtained with 30° pitch angle. In this case, however, the surface of the finished work is wavy. The smallest efficiency was obtained with the 70° pitch angle, but cutting is uniform in this case. The influence of the pitch angle on the cutting value can be seen from Fig. 11, where the chips obtained with the different cutters are shown. The weight of the chips is very variable, the figures given below the illustrations referring to the maximum weights which were obtained.

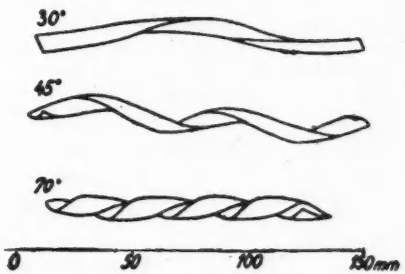


Fig. 11.

Weight of the chips from St. 50.11.

With pitch angle of 30°	4.6g.
With pitch angle of 45°	8.3g.
With pitch angle of 70°	13.8g.

CHARACTERISTICS OF ELECTROLYTICALLY PRODUCED OXIDE-LAYERS ON ALUMINIUM ALLOYS

By H. ROHRIG. (From *VDI, Zeitschrift Der Vereines Deutscher Ingenieure*, Vol. 84, No. 13, Berlin, March, 1940, pp. 223-225).

THE importance of surface enrichment of aluminium and aluminium alloys, by anodic produced oxide-layers, has increased during recent years. The method, generally known as "Eloxal" process, increases the resistance of light metals against corrosive action and improves the decorative effect of the metal. Further, a reliable electric insulation is obtained, resistive against temperature rises, and it can, according to the process, serve for reflecting heat and light rays. The manifold characteristics of the electrolytically obtained oxide-layer is not only based on the variety of the process, but is also determined by the nature of the material on which the oxide-layer is to be produced, or better still, by the surface on which the oxide-layer is produced.

Heterogeneously Separated Impurities effect the Oxide-Layer.

Similarly to other oxidizing processes the formation of the oxide-layer starts on the outside and proceeds towards the inside of the metal. The innermost surface of the oxide-layer is parallel to the outside surface as long as the work piece is of aluminium or a homogeneous aluminium alloy, but will become rough if heterogeneous constituents are embedded in the alloy, as for example silicon. This unevenness is considered to be due to the different specific resistance of the various substances.

It was found that corrosive attacks are prominent on the boundary layer of the oxide surface, and also in the region of the entectic, i.e., in contrast to unprotected metals, the adjacent metal was dissolved out from the oxide-layer. This is not surprising if we consider that in the case of a copper-aluminium alloy for instance the conversion of the oxide-layer produces a mixture of copper-oxide and aluminium-oxide. While the latter is a gamma oxide which is difficult to dissolve, the first one dissolves readily in weak solutions of acids. Due to the dissolving out of the copper-oxide, the mixture of aluminium-oxide and copper-oxide, which takes the place of copper-aluminium in the oxide-layer, becomes loosened. Hence, oxide-layers on homogeneous substances are more resistive against chemical action than those formed on heterogeneous substances.

Granular Structure Influences the Degree of Chemical Resistivity.

During the process care is taken not to exceed a certain limiting current density. Cast articles, as an example, may have a loose texture usually at the boundaries of the grains. These articles undergo enlargement of surface during the process, since the seams between the crystals are also being covered with an oxide-layer.

On the boundaries of crystals of separated impurities an oxide-layer can form more quickly. The result is that the current is no longer strong enough to produce the necessary thickness of oxide-layer.

Hardness and Wear.

These characteristics also are influenced, i.e., reduced by impurities enclosed in the material. It should be mentioned that on homogeneous aluminium-manganese alloy, oxide-layers can be produced as hard as those produced on pure aluminium.

Importance of the Crystalline Structure of the Material.

This can be seen from the shinyness produced on reflectors made from aluminium. The process is carried out in two steps. During the first part a reflecting surface is produced, and during the second part a clear covering layer is produced to protect the shiny surface. A good surface, however, can only be obtained if the crystalline structure of the semi-finished article is of very fine structure.

RADIANT HEAT—FULL FLEDGED INDUSTRIAL TOOL

By PAUL H. GOODELL, Manager, Radiant Heat Division, C. M. Hall Company, Detroit, Mich.

(From *Electrical Engineering*, Vol. 60, No. 1, January, 1941, pp. 3-8).

MOST industrial heating processes now rely on heat transfer by convection. With the intermediate heating of the air between the source of the heat and the work, two or more energy transfers result, with consequent loss in speed of transfer and efficiency, while the available radiant energy is largely converted into convected heat by the heat transfer system before it is usefully employed. The ability of radiant heat to warm objects apparently without regard to the surrounding air temperature has been known to man since his first exposure to the sun. Since the wave lengths longer than those of visible radiation and nearest the red end of the spectrum are responsible for this phenomena, the name infra-red has been applied for this radiation. In infra-red heating the energy is delivered directly from the source to the work in radiant form. Consequent convection from parts of elevated temperature is rather a secondary than an intended result.

In radiation heating the rate of temperature rise depends on the ability of the surface of the work to absorb the energy received. Mass, specific heat, and conductivity affect the temperature rise and the uniformity of temperature within the material being heated. The mean temperature finally attained is a matter of equilibrium, which occurs when the loss of heat is equal to the energy input. The higher the heat density applied, within the safe limits of the material involved, the faster and the more efficiently will the heat transfer be affected.

Surface reflection affects the rate at which energy may be absorbed. Mass, thermal conductivity, and surrounding air temperature affect the rate at which absorbed energy is dissipated. Research studies have been undertaken to determine suitable application of radiant energy. The chart in Fig. 1 gives the result of such a research.

Ordinary incandescent lamps, carbon as

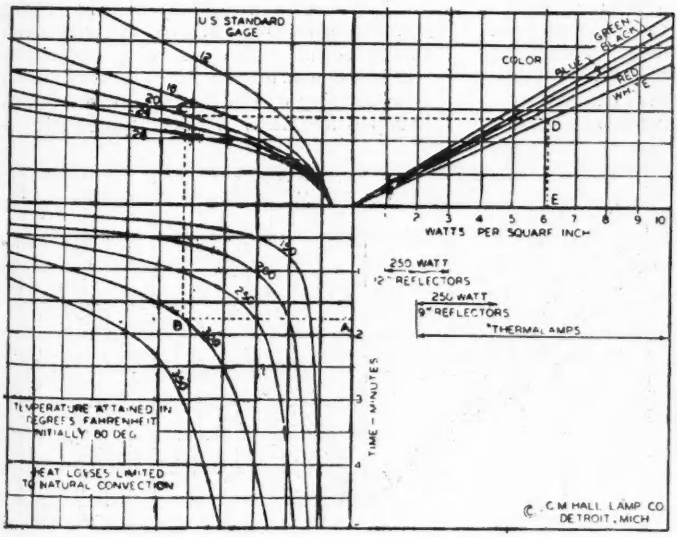


Fig. 1

Chart for computing time or heat density required to obtain desired temperature under various conditions of mass and colour.

Required heat density to obtain a given temperature in a given time. Starting with the given time (a) proceed clockwise following the dashed line to the desired temperature (b), to the gauge of sheet steel (c), to colour (d) and finally to (e), giving the required watts per sq. in. If time required to reach a certain temperature with a known watts per sq. in. is to be determined, the foregoing process is carried out in reverse fashion, starting at E and proceeding to A.

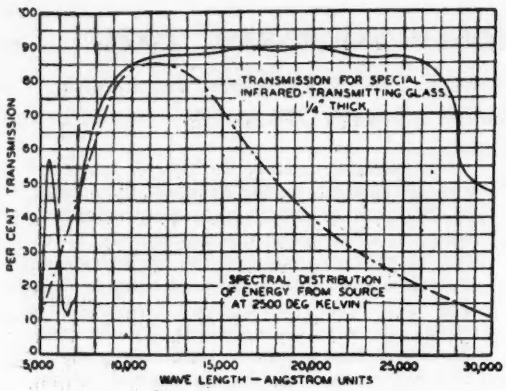

PER CENT TRANSMISSION
TRANSMISSION FOR SPECIAL INFRARED-TRANSMITTING GLASS 1/4" THICK
SPECTRAL DISTRIBUTION OF ENERGY FROM SOURCE AT 2500 DEG KELVIN
WAVE LENGTH — ANGSTROM UNITS

Fig. 2

Energy distribution from a radiant heat source, and characteristics of an infra-red-transmitting glass.

well as tungsten lamps, when operated at slightly lower filament temperature, than when used for illuminating purposes, approximately at 2500°K, provide an extremely efficient, long-life source of infra-red radiation.

The effect of various wave lengths on materials is different. Water films are excellent transmitters of wave lengths below 11.000 A.u. Pigments used for paint finishes vary considerably in their absorption characteristics to energy from 7.000 to 30.000 A.u. But this is of little consequence to the efficiency, as the energy is converted from radiant into physical form within the paint film or by conduction from the underlying surface. But energy subject to reflection has to be held to a minimum. This applies especially to shorter wave lengths, approaching the visible spectrum, which may be reflected particularly by light coloured objects. Fig. 2 shows the spectral distribution from a source operating at 2500°K. (slightly over 4000°F.), and the transmission characteristics of a special type of glass well suited to the transmission of radiant heat.

Application of Radiant Heat.

For the present, radiant heat is primarily used for low-temperature heating of physical objects. The practical limit with present-day equipments is approximately 600°F. Lamp ratings vary from 250 to 1000 watts; lamps are available for all standard industrial distribution voltages. With these lamps heat densities may be provided up to approximately 10 watts per sq. in. (1 watt per sq. in. = 491.5 Btu per hour and sq. ft.). The lamps are used with reflectors. Both open and enclosed reflectors are available with aluminium or gold employed as the essential reflector surface. Gold provides the highest known reflection of infra-red energy, being approximately 97% efficient. Chemically oxidized aluminium reflects from 75 to 91% by comparison.

Fortunately for radiant heating, baking processes involving oxidation are very much on the decline. Oils are being replaced by synthetics, which will cure by polymerization as rapidly as the heat transfer can be effected. But polymerization requires appreciable ac-

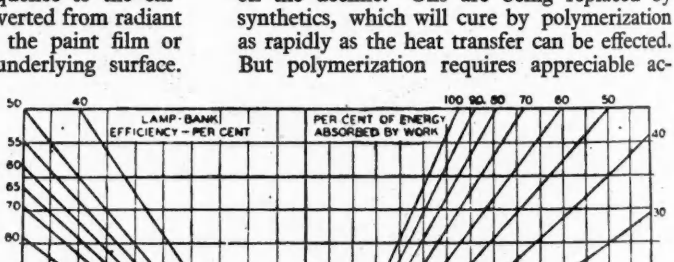


Fig. 3

Chart for graphical computation of power required for water evaporation.
Starting with a given weight of water (a) proceed clockwise to lamp-bank efficiency (b), to absorption % (c), to final answer D. Chart based on initial water temperature of 70 °F.

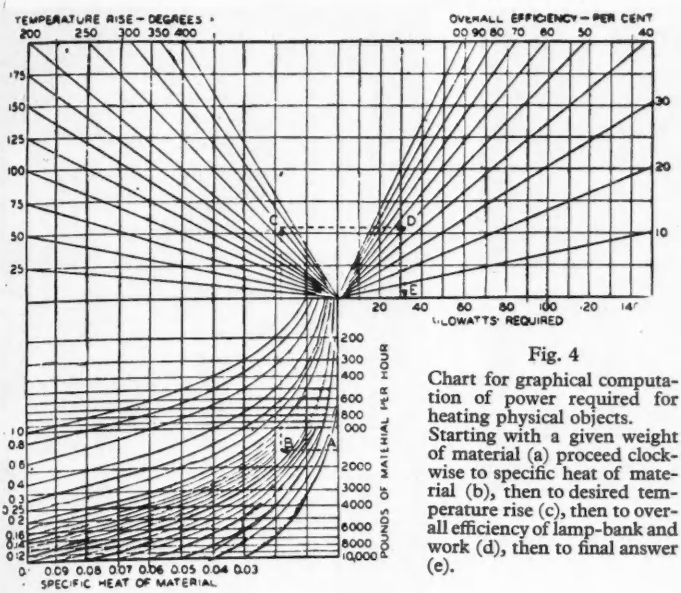


Fig. 4

Chart for graphical computation of power required for heating physical objects. Starting with a given weight of material (a) proceed clockwise to specific heat of material (b), then to desired temperature rise (c), then to overall efficiency of lamp-bank and work (d), then to final answer (e).

curacy, both as to time and to temperature of bake. Even in the simple dehydration processes, competition from generally lower-cost fuels compels the careful study of evaporation rate with consequent adjustment in the density of energy applied throughout the operation.

New optical principles have had to be introduced in order to avoid serious variations in heat density over a practical range of working distances from the equipment, and applications involving materials of low thermal conductivity have necessitated improvements in the uniformity of heat production. The heating capacity of a radiant heating device may be determined in the same manner as it would for any other type of heating. Fig. 3 shows a graphical means for determining the approximate kW capacity needed for evaporating water at various rates. Fig. 4 provides a chart for the calculation of the required kW capacity of an oven for raising the temperature of physical objects, when the overall efficiency of heat transfer is known. Efficiency varies with the duration of the heating cycle—it is better with short cycles—and is also affected by many physical factors of oven design.

In some instances high rates of heat transfer, combined with proper chemistry of materials, may produce phenomenal results.

Other applications, however, may prove to be entirely impractical, while some may or may not be as economical as other methods of heating due to individual conditions. Fig. 5 illustrates a typical high-heat-density installation of 96 kW before draft shields and ventilating equipment had been installed. Fig. 6 shows a completed low-heat-density installation of 22.5 kW. For some work portable banks may be the best type of heating device.

Advantages and Uses.

The high temperature sources provide an instantaneous source of heat, thus eliminating warm-up time and losses during the warm-up period. Working conditions are improved, as air temperatures are not raised. Elimination of fumes resulting from combustion of fuels contributes to improved working conditions. First cost is low. The structure of the heating device may be limited to a light skeleton frame. Draft shields may be employed to minimize convection losses, and exhaust hoods may remove objectionable fumes. The installation possesses utmost flexibility for plant changes; varying types or sizes of work may be accommodated in the same oven by advantageous conversions. The light-weight construction permits hanging ovens from the ceiling, allowing the free use of floor space below.

The easy control and change of density of radiation enables the application of the most effective heat concentration in each stage of a process and the reduction of a heating cycle to a minimum of time. With convection practice the same process would necessitate sectionalized oven constructions,

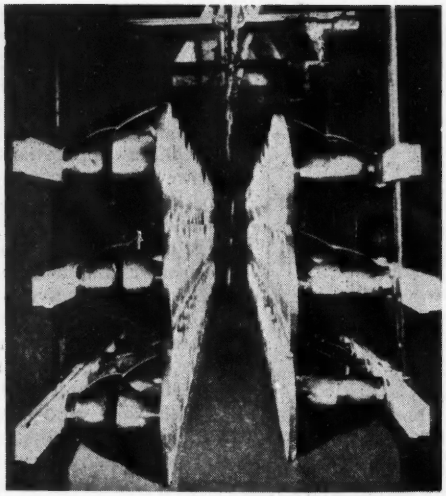


Fig. 5

Typical high-heat-density radiant oven. Bakes a weather-resistant finish on heavy-gauge parts in 3½ minutes.

at greater cost. Saving in space and time can be achieved with the radiant heating system, and automatic handling can be facilitated. Many industrial finishes to-day are being baked in less than two minutes.

At present radiant heating is primarily employed for the low-temperature heating of metals and plastics, the baking of paints and insulating varnishes, and a great variety of dehydration operations. Plans are in process for extending it into other fields, particularly where chemical operations may be accelerated.

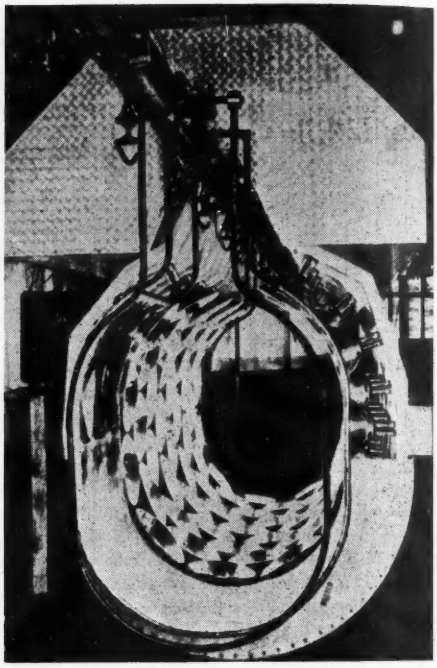


Fig. 6

Typical low-heat-density radiant oven.

Few developments in the last decade have been so revolutionary or have offered such promise for future expansion of the electrical industry as this one, which had its inception for production application in the plants of the Ford Motor Company.

THE PROCESS OF COMBUSTION IN ANTI-CHAMBERS

By DR. ING. K. SCHNAKIG. (From "*MTZ*" *Motortechnische Zeitschrift*, March, 1940, Vol. 2, No. 3, pp. 69-75).

THE process of combustion in the anti-chamber was first investigated in a Körting engine. Later, measurements of temperatures and pressure were taken at different stages of the combustion, and also samples of the combustible mixture were analysed. These experiments were repeated on a larger scale on a high speed experimental engine (Fig. 1). This engine was a two-cylinder four-stroke Deutz engine, delivering 3 h.p. at 1300 r.p.m., with a compression ratio 1:16.5, the volume ratio of the anti-chamber to the total clearance volume being 1:2.2, and the ratio of the area of the four channels from the anti-chamber to the main chamber to the surface area of the piston being 1:180. Injection took place at 125 atm. pressure, through a nozzle of 0.6 mm. dia. Samples of gas were extracted at 5 different points of the clearance volume, as shown in Fig. 2, through a water cooled valve controlled

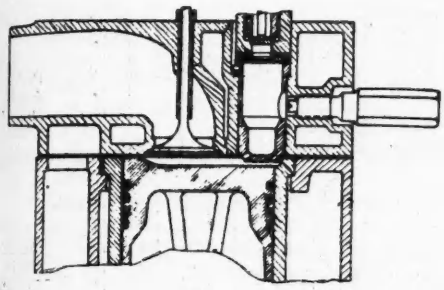


Fig. 1.

by the cam shaft. The time of valve opening was 6° crank shaft angle. This was measured by the following electrical measuring instruments:

(Fig. 3). The brush spring (e) is rotated in the direction of the rotation of the crank shaft until the semi-incandescent lamp (g) does not light any more, i.e., the closing of the contact (d) coincides with the opening of the contact (h), which is initiated by the opening of the valve. This point, as indicated on the scale on the insulator, gives the angle at which opening starts. The point of valve closing is simply determined by rotating the contact (c) further, until the lamp is lit again. The angle of valve opening is given by the difference in the two readings on the scale.

The objections brought up against the experimental values obtained from the analysis of the gas samples are:

1. The gas is taken from near the walls, where the temperature is not so high, and the gases are not taking such active part in the process of combustion.

2. The sample is not an average of the combustible mixture.

3. The extraction of the gas disturbs the process of combustion.

4. The gas sample undergoes further changes in the valve, *e.g.*, further burning.

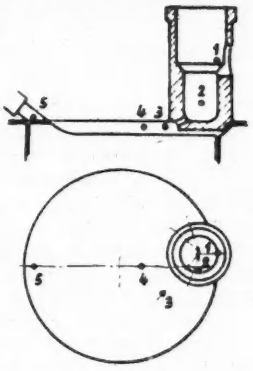


Fig. 2.

The answers to these objections are as follows. The effect of the wall on the combustible mixture is greatly reduced by the turbulence in the clearance volume. It was found by taking samples from various parts of the clearance volume that the sample of gas is a fairly good average of the combustible mixture. The time taken for extracting 500 cm^3 of gas was 1 minute, hence 0.77 cm^3 gas is extracted during one revolution, which is a negligible quantity compared with the total charge present, hence it will not have much effect on the combustion. And, finally, the changes which the gas undergoes in the valve during extraction can be reduced by proper water cooling of the valve.

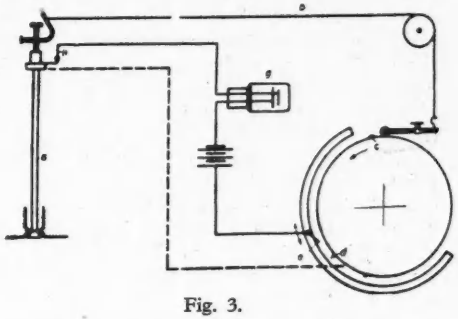


Fig. 3.

The experimental results based on the gas analysis are shown in Fig. 4. It can be seen from the graphs that combustion is taking place mainly at point 2, i.e., near to the hot lower surface of the anti-chamber. On the other hand no combustion is taking place at point 5, the slow rise in the CO_2 content is more probably due to turbulence than to combustion at this point. Also at point 2 the oxygen content falls rapidly (almost immediately after ignition) to a very low value, i.e., combustion is taking place in insufficient amount of air.

Turbulence, however, is quickly increasing the oxygen content. The abrupt stopping of combustion after ignition can also be seen at point 3. In the main combustion chamber the CO_2 content drops temporarily. But this being accompanied by an increase in O_2, it can be attributed to the blast of burning products coming from the anti-chamber. Due to this blast the turbulence is increased and fresh air,

not yet taking part in the combustion, is reaching the ports leading to the anti-chamber, and hence the gases find suitable conditions for complete combustion. However, the actual combustion in the main combustion chamber starts only after the second blast from the anti-chamber. (Compare with Fig. 4).

At point 1 a considerable amount of CO and hydrogen is present, even when combustion is well in progress. This indicates that due to the lower temperatures at the upper part of the anti-chamber, combustion is not so readily taking place at this point.

Altogether from Figs. 1-4 the conclusion can reasonably be drawn that combustion is starting at point 2, near the bottom of the anti-chamber. The blast is not sufficient to bring about a uniform charge distribution in the main combustion chamber, since no combustion is taking place at the far end, i.e., at point 5. The amount of air present is sufficient, since after combustion CO can only be found in traces at points 3 and 4.

The quantity of excess air at the various points were also calculated from the examination of the products of combustion. Again it was ascertained that there is insufficient air at point 2 and also at points 1 and 3 to a lesser amount. Excess air is always present at point 4. (See Fig. 5, and note: the total air content of the anti-chamber would be sufficient for complete combustion of the fuel present if it were uniformly distributed). The carbon deposit of free carbon content was calculated for points 1, 2, and 3, and the result is given in Fig. 6. These figures, however, must not be regarded as very accurate ones, since errors in the gas analysis are magnified when calculating the free carbon content. However, it can be seen that a fairly large amount of free carbon is formed at point 2, and this is blown into the main combustion chamber.

Similar results were obtained with various loadings and speed of the engine.

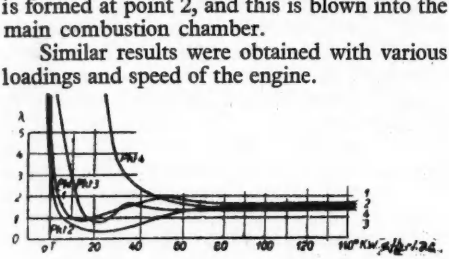


Fig. 5.

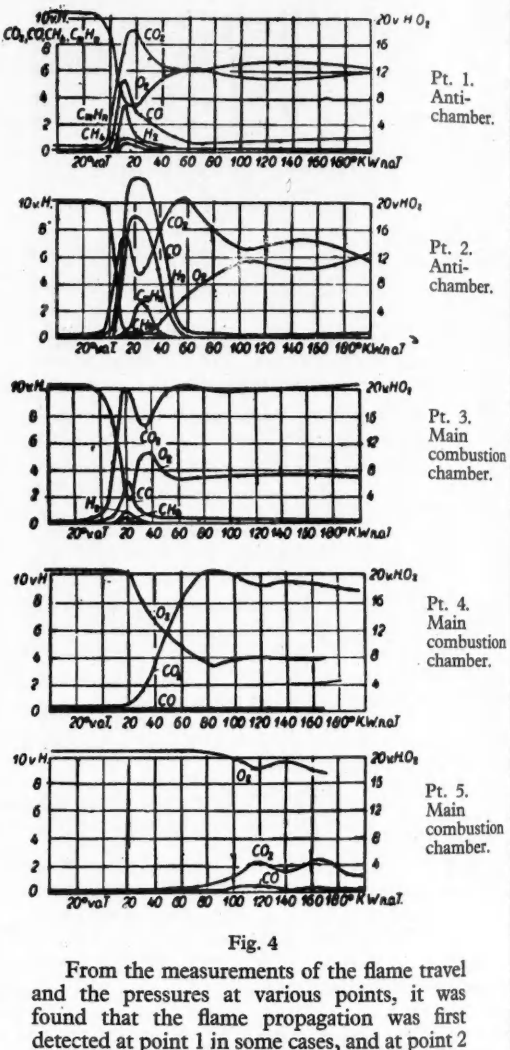

Pt. 1. Anti-chamber.
Pt. 2. Anti-chamber.
Pt. 3. Main combustion chamber.
Pt. 4. Main combustion chamber.
Pt. 5. Main combustion chamber.

Fig. 4

From the measurements of the flame travel and the pressures at various points, it was found that the flame propagation was first detected at point 1 in some cases, and at point 2 in other cases. Most probably, ignition starts somewhere between points 1 and 2. The indicator diagrams taken from the anti-chamber are also supporting this assumption. The latter show a shorter ignition lag than the measurements of flame propagation. This fact can be explained by assuming the ignition to start between points 1 and 2, since

the pressure waves travel faster than the flames

Figs. 7 and 8 show the ignition lag as a function of the load and the r.p.m. obtained by measurements of ionization and pressures. It can be seen that increase in the revolutions means a decrease in the lag, also that it is not greatly affected by varying the starting point of the injection.

The flames are reaching the points 4 and 5 very irregularly, and also the intensity and duration of the flames are not constant. This, again, is an indication that the fuel distribution in the combustion chamber is not uniform. Not so for points 1 and 2, where almost identical results were obtained for the consecutive revolutions. Further, the differences in the time of the starting points of the ignition are very small, indicating that the combustion fills quite suddenly the anti-chamber up to about half-way.

In Figs. 9 and 10 the results are shown obtained by the measurements with electrodes. The line of ionization of the point 3 is in line with the blast coming from the anti-chamber. The results also show the time taken from injection until the first reduced pressure rise, as, for instance, in case of delayed injection. This first kink in the graph (mainly on anti-chamber indicator diagrams) is probably due to chemical reactions. The fuel vapours present in the anti-chamber are decomposed, and they take up oxygen. The oxides thus formed are very unstable, and give out heat on decomposition. This is accompanied by a rise in temperature and pressure, hence the reaction is speeded up, and results in a considerable rise in the pressure.

Throttling is taking place between the anti-chamber and the main combustion chamber.

The pressure in the anti-chamber rises above that in the main combustion chamber, and then remains above it for the rest of the combustion. This fact indicates that a great

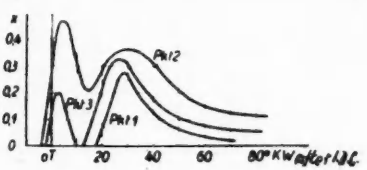


Fig. 6.

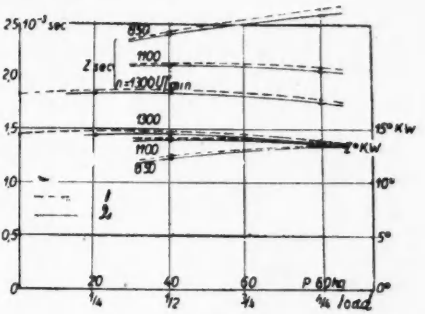


Fig. 7.
1 Flame measurements at point 1, 2 pressure measurements at point 1.

proportion of the fuel is being burned in the anti-chamber. The increase in pressure in the anti-chamber at ignition has values between 60-90.000 atm sec., which is equivalent to 8-12 atm degree of crank shaft. For the main chamber this figure is only 30-60.000 atm sec.

Summarizing the results it can be stated:

1. Ignition starts at the lower surface of the anti-chamber.

2. A great proportion of the fuel is burned in insufficient amount of air (in the anti-chamber), hence a considerable amount of free carbon is formed.

3. The fuel is not uniformly distributed in the main combustion chamber.

Thus the process of combustion in this type of engine is not satisfactory, although the fuel consumption figures are favourable when compared with other types of engines. The reason for introducing an anti-chamber in the cylinder head is to start the combustion here,

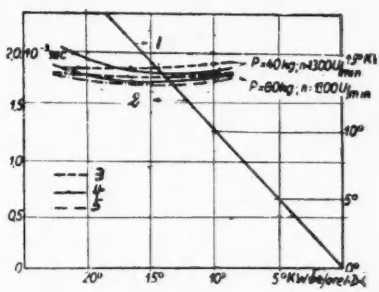
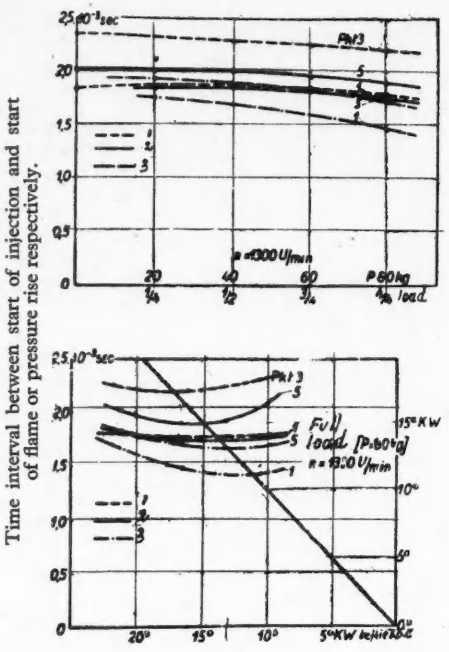


Fig. 8.
Starting point of the injection.


Time interval between start of injection and start of flame or pressure rise respectively.
Full load
n = 1300 U/min
n = 1900 U/min
P 60 kg
full load

Figs. 9 and 10.

1 Starting point of flame, 2 Rapid pressure Rise, 3 slow pressure rise.

and the bulk of the fuel should then be quickly blown into the main chamber. Hence it would be required that only so much fuel should burn in the anti-chamber as is necessary to produce the rise in the pressure to blow the remaining charge into the main chamber, where it should be distributed uniformly. In order to achieve this result, the fuel and the air should be separated in the anti-chamber. This condition, however, is not obtained in practice.

Deutz has designed an improved cylinder head, which has a much smaller bottom part in the anti-chamber, and it is found that this engine gives better results.

Further investigations on other anti-chamber designs showed the great influence of the shape of the anti-chamber on the fuel consumption figure.

It seems to be desirable to design an anti-chamber and an injector so that the bulk of the narrow and well atomized fuel spray shall penetrate the bottom part of the anti-chamber. The vapours should collect in the upper part. Sufficient air must be available to start the ignition, driving the fuel in the lower part quickly into the main chamber. Strong blast is required, especially for engines having the anti-chamber on the side of the cylinder head, to ensure a uniform fuel distribution in the main chamber.

ZERO-THRUST INDICATOR AND ELEVATOR LOCKING DEVICE: TWO NEW AIDS TO FLIGHT MEASUREMENTS

By W. STIESS. Report of the Dornier-Werke G.m.b.H., Friedrichshafen a.B.

(From *Luftfahrtforschung*, Vol. 17, No. 8, August 20th, 1940, pp. 236-238).

1. The Zero Thrust Indicator.

The comparison of results obtained by flight tests with those on models is often very difficult owing to the fact that with throttled down engines there is a definite thrust or drag from the air-screws.

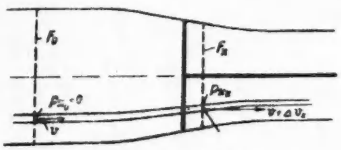
The direct measurement of thrust is well developed but not easily practicable for purposes of the industry.

With a simple device, placed behind the controllable pitch air-screw, measuring the average total pressure at zero-thrust, the advance ratios of the air-screw can be determined with sufficient accuracy.

Measuring the pressures and velocities at a flow section just behind the air-screw the thrust can be calculated by using the Impuls-law.

Denotation [see Fig. 1]:

S = thrust
γ = specific weight of air
g = acceleration due to gravity
v = airspeed
Δv = increase in airspeed



Area of annulus d F_x

Fig. 1.

F = area of flow-section
q = dynamic pressure
p_{tot} = total pressure
p_{st} = static pressure.

Indices O and X denote the flow-section in front of and behind the airscrew respectively. Thus,

$$q_x = p_{totx} - p_{stx} = \frac{\gamma}{g}\frac{(v+\Delta v_x)^2}{2},$$

and

$$p_{toto} = \frac{\gamma}{g}\frac{v^2}{2}$$

$$S = \int^{Fx}\left[\, 2\frac{\gamma}{g}\frac{(v+\Delta v_x)^2}{2} - 2\frac{\gamma}{g}\frac{v^2}{2} - \frac{\gamma}{g}v\Delta v_x + p_{stx}\right] d\,F \quad \text{.....(1)}$$

or

$$S = \int^{Fx}\left[\, 2\left(p_{totx} - p_{toto}\right) - \frac{\gamma}{g}v\Delta v_x - p_{stx}\right] d\,F \quad \text{.....(2)}$$

Therefore, to obtain a finite value for S, the total pressures as well as the static pressures at section X should be measured. As the measurement of p_{stx} becomes difficult owing to interference with the engine nacelle and fuselage, the total pressures at the sections O and X are being measured only, whereby considerations are limited to a single case, viz., to zero-thrust conditions alone. To this end the airscrew-pitch is varied until the integral $\int^{Fx}(p_{totx} - p_{toto})\, d\,F$ becomes zero. It is sufficient to measure the average value of p_{totx} along one radius only, as the total pressure remains practically constant.

It follows, that for the condition $p_{totx} = p_{toto}$:

$$p_{stx} + \frac{\gamma}{g}\frac{(v+\Delta v_x)^2}{2} = \frac{\gamma}{g}\frac{v^2}{2} \quad \text{.....(3)}$$

and therefore,

$$\frac{v\Delta v_x}{g} + \frac{p_{stx}}{\gamma} = -\frac{\Delta v_x^2}{2g} \quad \text{.....(4)}$$

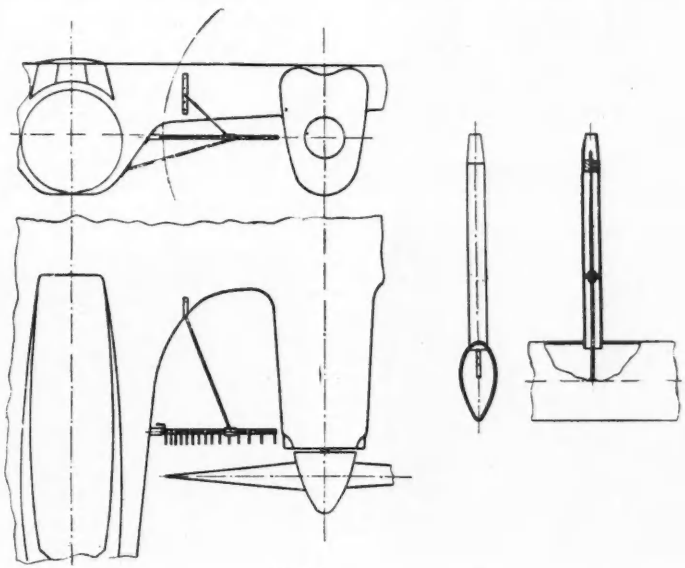


Fig. 2.

Thus, from equation (2)

$$S\,(p_{tot_x}=p_{tot_0})=\int^{F_x}\frac{\gamma}{g}\frac{\Delta v_x^2}{2}\,dF,$$

whereby from (4)

$$\Delta v_x=-v+\sqrt{v^2-\frac{2g}{\gamma}p_{st_x}}\qquad\ldots\ldots\ldots(5)$$

The remaining average value of the difference between the static pressures in front of the airscrew and behind it, is negligible compared with $\frac{\gamma}{2g}v^2$.

Figs. 2 and 3 show the installation of the device on a Do 17 aeroplane; the detail picture in Fig. 2 shows a single tube with a capillar for measuring of p_{tot_x},* connected to the main tube (which in turn is placed radially just behind the airscrew). The distance of the single tubes is stepped so that the annular area between two consecutive tubes remains constant. A tube connects the device with a pressure gauge which measures the average p_{tot_x} against p_{tot_0}. The latter is derived from the Pitot-tube of the speedometer.

The test results for four different speeds (v_A = 170, 185, 220 and 280 km/h.) are shown in Table 1; for zero indication of the pressure gauge, airscrew-pitch, r.p.m., and dynamic pressure were read off. (Circumferential speed u in m/sec, pitch angle β at 0.7 of the radius.)

*See: Kramer—Doetsch, Jahrbuch, 1937, der Deutschen Luftfahrtforschung I., p. 59.

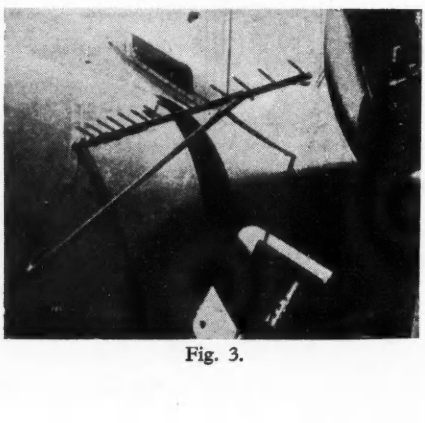


Fig. 3.

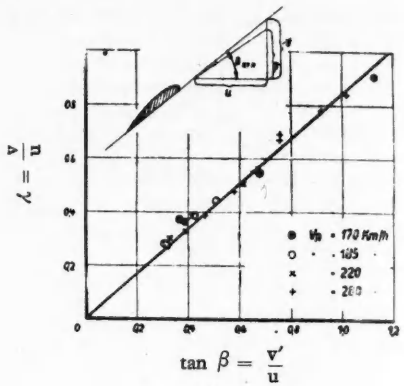


Fig. 4.

Finally, in Fig. 4, the zero-thrust advance ratios $\Lambda = \frac{v}{u}$ are plotted against the geometrical advance ratios $\beta = \frac{v'}{u}$, and it can be seen that the test results are in good agreement with the theoretical straight line.

2. The Elevator Locking Device.

For flight tests with rigid elevator a device has been developed which enables the pilot to lock the elevator in neutral position. The safety of flight is fully ensured, as a strong push or pull on the control column invariably causes to unlock the elevator.

Fig. 5 shows the device mounted on the stabilizer of a Do 17 so that if actuated it locks the mass-balance lever.

Fig. 6a is a diagrammatical view of the device, mounted on one of the levers to which

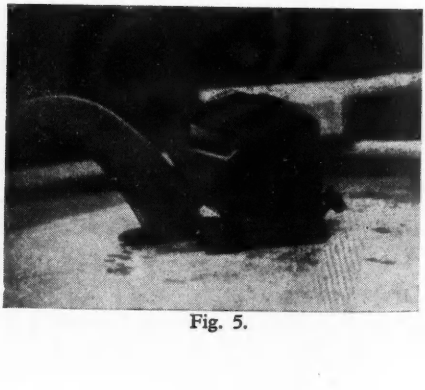


Fig. 5.

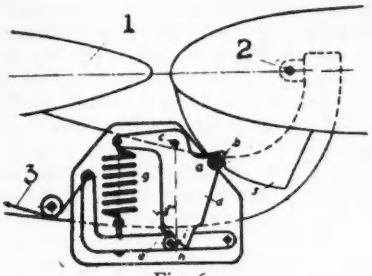


Fig. 6a.

1 Stabilizer, 2 Elevator hinge, 3 Cable.

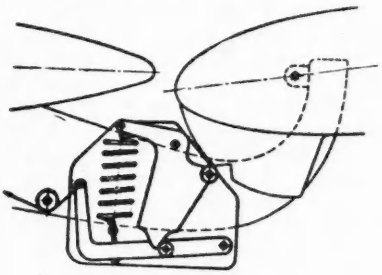


Fig. 6b.

the elevator is hinged. Instead of the mass-balance lever, a cam S is provided which is notched at *b* as to be locked in the desired position by snapping in of a small roll a. Roll a is under the influence of spring g, the initial tension of which can be conveniently changed. Lever d turns about pivot c. Spring g is fixed at the other end to lever e, which carries roll h. This is done as to achieve great forces with a relatively weak spring, whereby the edge i of lever d resting on h forms an acute angle γ with a ray from pivot c. Lever e is actuated by pulling the cable; the peculiar shape of lever d in conjunction with its position to roll e can be clearly seen in Fig. 6b, which for the rest is self-explanatory.

TABLE I.

Zero-thrust advance ratios λ:

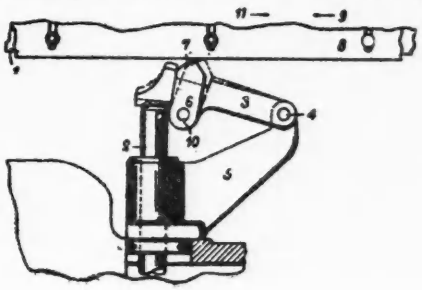
v_A	v	u	$\lambda = \frac{v}{u}$	β	tan β
170	45.3	158	0.287	17.5	0.315
170	44.2	121	0.374	20	0.364
170	45.5	50	0.910	48.5	1.13
170	45.5	84	0.542	34	0.674
170	45.5	126	0.360	21	0.384
185	49.8	112.5	0.443	26.7	0.503
185	51.5	185	0.278	17	0.306
185	50.7	131	0.388	23	0.425
185	49.9	101	0.494	29.5	0.425
185	50.8	185	0.275	17.5	0.315
220	62.6	163	0.385	22.5	0.414
210	59.9	118	0.507	31.3	0.613
220	61.3	186	0.329	20.7	0.378
220	60.8	203	0.300	18	0.325
280	83	215	0.385	24.8	0.462
280	80.8	169	0.478	30	0.578
280	79	102.5	0.780	42.5	0.917
280	78.8	118	0.670	37	0.755
280	85	101	0.840	45.5	1.019
280	82.2	119	0.690	37	0.753

Diameter of airscrew = 3.2 metres.

PATENTS AND INVENTIONS

Machine Tools with Hydraulic Controlling Device, the pump piston having different surface areas. Such machines are usually fitted with hand regulator to give a different pump delivery for the forward and return stroke. Hence the speed in both directions will be the same. The invention of the Cincinnati Milling Machine Co. offers a solution to arrange automatically an identical speed in both directions of the stroke.

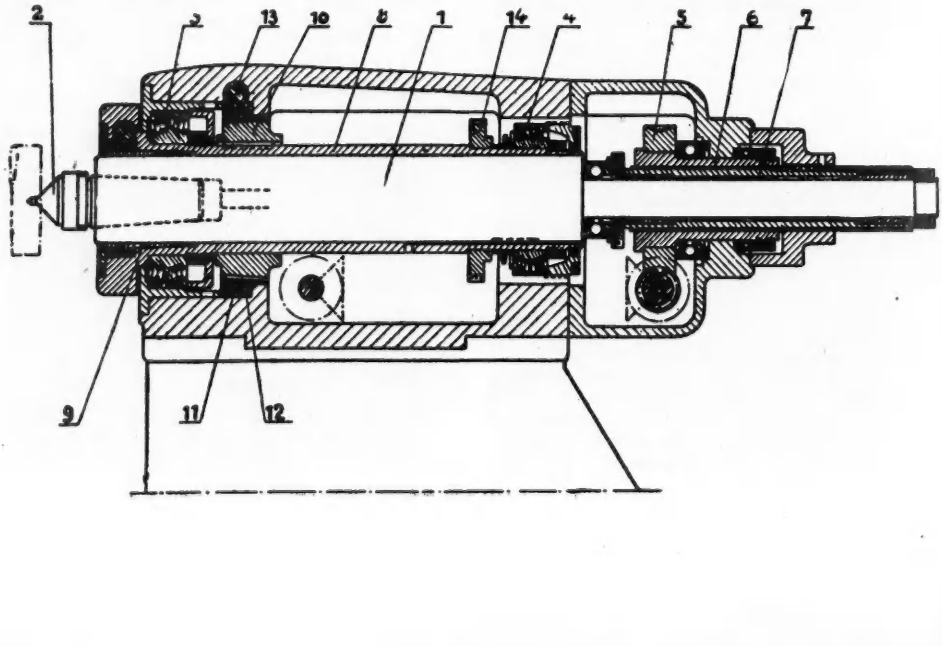
The table (1) is moved by a double acting pump (not shown), the piston areas of which are different at the two sides. The delivery of the pump determining the speed of the feed can be regulated by an adjusting rod (2). An adjusting lever (3) is pivoted to a support (5), and rotates about point (4). The end of the lever (3) rests on the top of the rod (2). A hinged catch (6) is attached to the lever (3) so that the pointed end of the catch is touching



the slide rail (8). The latter is fixed to the table. If the pump is connected to the smaller chamber of the feed cylinder the table is shifted in the direction of the arrow (9). During this movement the catch (6) is moved by the friction of the rail to the position shown in full lines, and hence (2) is pressed down to the position also shown in full lines. Thus the delivery of the pump is automatically reduced. If the pump is connected to the other side of the cylinder, movement of the table in the direction of the arrow (11) takes place. This time the catch is brought to the position shown in dotted lines, and hence the delivery of the pump is increased to the initial value.

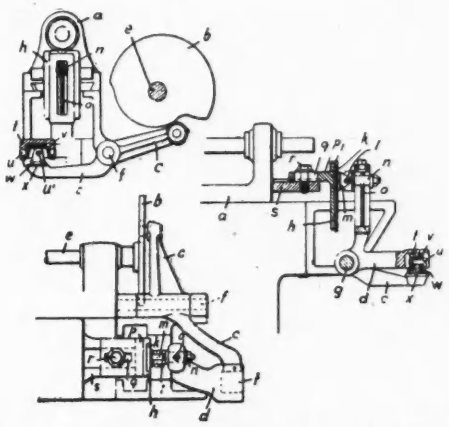
Bedding of Rotating Back Centres in the Sliding Headstock of a Heavy Duty Lathe. (DRP 671 058, *Machinenfabrik Froriep*). If the work piece is of large weight it is not sufficient to suspend it on the point of the back centre, but it must be fixed to a front frame attached to the back centre, and hence the latter is also rotating. The back centre (1) is bedded in the roller bearings (3) and (4), and can be adjusted in the longitudinal direction by the worm wheel (5). The worm wheel is seated on a nut (6) fixed on a hollow spindle (7). The back centre sliding in the cylinder (8) can be fixed in any required position by a conical box (9). (10) is a tube conical inside and cut with a thread on the outside. A spur wheel (14) is fixed on to the cylinder (8) driven by the motor through various intermediate wheels. (11) is a box moved by a worm wheel (13). If (11) is adjusted and tightened up to the cone (10) the back centre operates as an ordinary one, i.e., it is fixed. If the box (11) is released the back centre can rotate, the pressure exerted on it being taken up by the respective bearings.

Automatic Feed Device for the Mandrel Stock of a Lathe. (DRP 670 116, by J. Streicher). The head stock (a) is moved by a suitably shaped rotating disc (b), the feed being transmitted by the levers (c) and (d). The lever (c) is moved directly by the disc (b), and transmits the movement to the lever (d), which, in turn, engages the head stock in its perpendicular middle plane. The lever (c) can swing round (f) perpendicular to the direction of the feed of the head stock. The lever arm (d) can swing round (g), i.e., in the direction of the feed. It engages the head stock through a sliding contact. This consists of a perpendicular plate (h) at the back side of the head stock with sliding surfaces (i) at right angles to it. A slider (k) is fixed to the upright standing end of the lever (d), and can slide on the surface (i). The attachment of (k) to the lever (d) is made by a pivot (l) in the horizontal



plane, perpendicular to the axis of the spindle, so that when (d) is swinging, the sliding surface of (k) remains in the vertical plane. The slider (k) is adjustable in the vertical plane, the pivot (l) being fixed to a nut (n), which can be adjusted by turning it on a spindle (o). The slide plate (h) is adjustable in the direction of the feed, since it is attached to the lever (p), which, by means of a slot (q), and a fixing bolt (r) passing through the slot, can be adjusted and fixed in the required position on the arm (s).

The sliding contact connecting the lever (c) and (d) consists of a pivot (t) fixed to the back end of the lever (d), which can swing round a pivot (u) parallel to the pin (g). A second loose swinging pivot (r) is connected to (t), and can rotate round the pin (u) parallel to the pivot (f). The turning joint (v) is provided with a sliding guide shoe (w) on its bottom surface, and the lever (c) is provided with a sliding surface (x) on the inner lever arm. The



turning joint (v) slides on the surface (x), due to the movement of (c) and (d), and transmits the swinging motion of (c) to (d).

PRINCIPLES OF JIG AND FIXTURE PRACTICE

By JOSEPH W. ROE. (From *Mechanical Engineering*, Vol. 63, No. 2, February, 1941, pp. 117-24).

THE combination of a machine tool and the jig or fixture which forms its work-holding equipment must do two things. It must drive a cutting tool of proper form and material in a motion which is exact as to path and often as to distance travelled. It must also hold the work in exact relation to the cutter. Precision in setting and holding the work is as important as precision and power in cutting. No amount of excellence in the machine is of use if the work-holding device is weak or inaccurate. The terms jig and fixture are often used interchangeably. In so far as they are differentiated a fixture is a work-holding device, usually secured to the table of a machine, while a jig is usually free to centre itself on the cutting tool.

Economic Principles.

The most important element, which applies to all forms of work-holders, is the economic one. The question of the amount of expense justified has been handled largely on the basis of judgment. The besetting sin of the toolmaker is to tie up money in fixtures which may show a heavy saving when in use, but are seldom used. A saving of 5% in labour cost on a job in constant use might justify greater expense in fixtures than a saving of 90% on a small job coming through only once or twice a year. Other factors besides saving in time and labour expense are involved, such as the life of the fixtures, due not only to their own wear, but to possible obsolescence of the article they make. Fixtures may be desirable even where only small quantities are involved, but the economic advantage of lower labour costs is the controlling factor, unless some other consideration, such as improved interchangeability, increased accuracy, or reduction of labour trouble intervenes. Usually, where these latter reasons alone would have necessitated a fixture, it is found that the fixture lowers costs.

Few plants give to their fixtures the searching economic analysis which they apply to their power equipment. Thanks to the Materials Handling Division of the American Society of Mechanical Engineers, formulas are now available, and are being increasingly

used, which provide a standard basis for the economic analysis of equipment in that field, and for determining the probable profit on any proposed installation for given costs and performance. These formulas take into account interest, depreciation, obsolescence, and other items of overhead which theretofore had been either neglected entirely, or had been handled differently by everyone concerned. They can be used, with modifications, for tool equipment just as well as for materials-handling equipment, and should be.

In dealing with fixtures, the economic problem centres on answering one or more of the following questions:

(1) How many pieces must be run to pay for a fixture of given estimated cost which will show a given estimated saving in direct labour cost per piece ?

(2) How much may a fixture cost which will show a given estimated unit saving in direct labour cost on a given number of pieces ?

(3) How long will it take a proposed fixture, under given conditions, to pay for itself, carrying its fixed charges while so doing ?

Questions 1, 2 and 3 assume that we just break even. There is also the very practical question:

(4) What will be the profit earned by a fixture, of a given cost, for an estimated unit saving in direct labour cost and given output ?

An important time element is that many companies now require that any new equipment shall pay for itself in a certain period. Various investigations show wide variations in practice as to this requirement, ranging from one to six or seven years, the longer period being used by railroad shops, which have a stable class of work not liable to rapid obsolescence. The general practice seems to be about two years.

Proposed Equipment Formulas.

Symbols used: let N = number of pieces manufactured per year.

Debit Factors:

A = yearly percentage allowance for interest on the initial investment. (If the interest be taken on the depreciating value, this becomes, under uniform depreciation for n years, $A \times \frac{1}{2}\frac{n+1}{n}$, the value of which decreases from A, for one year, and approaches A/2 as n grows large.

B = yearly percentage allowance for insurance, taxes, etc.

C = yearly percentage allowance for upkeep.

1/H = yearly percentage allowance for depreciation and obsolescence on the basis of uniform depreciation where H is the number of years required for amortization of investment out of earnings.

E = yearly cost of power, supplies, etc., consumed. In many cases, with fixtures this item is small and may be disregarded. (It is a debit if the E on the new equipment exceeds that on the old. It is a credit if the new E is less than the old. E in the formula may therefore be + or —).

I = estimated cost of the equipment or fixture, i.e., cost installed and ready to run.

K = unamortized value of the equipment displaced, less scrap value.

Y = yearly cost of set-ups. This should include the time required for taking down the apparatus and putting the machine into normal condition.

Credit Factors:

S = yearly saving in direct cost of labour.
= N × (old unit labour cost, minus the new unit labour cost).
= N × (saving in unit labour cost).
= Ns. This covers unit direct labour cost only.

s = saving in unit labour cost.

T = yearly saving in labour burden.
= St, where t is the percentage used on the labour saved.
= Nst.

U = yearly saving or earning through increased production.
= saving in unit labour cost × increased yearly production capacity.
× the percentage of that increased capacity which will be utilized.

$\times$ (1+t) (this takes care for the burden saved).
+ cost of extra old equipment which would be necessary to care for the increase if the improvement were not adopted.

V = yearly net operating profit, in excess of fixed charges.

Proposed Formulas.

If we just break even we have:

The yearly operating savings = total fixed charges per year.

Hence: (S+T+U—E)—(Yearly cost of set-ups) = I (A+B+C+1/H)+KA, since S+T = Ns+Nst= Ns (1+t).

(1) Then: Ns (1+t)+U—E—Y = I (A+B+C+1/H)+KA.

To find the number of pieces required for a given cost we have, solving for N

$$(2)\quad N = \frac{I(A+B+C+1/H)+Y-U+E+KA}{s\ (1+t)}$$

To find the cost I which will just earn fixed charges we have, solving equation (1) for I

$$(3)\quad I = \frac{Ns\ (1+t)-Y+U-E-KA}{A+B+C+1/H}$$

(4) To find the net operating profit over all fixed charges we have V = gross operating profit, less set-ups and fixed charges = Ns (1+t)—Y—I (A+B+C+/1H)+U—E—KA

To find the time H in years for the fixture to just pay for itself, the net profit V in equation (4) = O.

(5) Therefore, setting the right hand side of Equation (4) equal to O and solving for H, we have

$$H = \frac{I}{Ns\ (1+t)-Y-I\ (A+B+C)+U-E-KA}$$

(6) In most cases it will be found that U, E and KA may be neglected, so that Equations (2) (3) (4) and (5) may be written as follows:

$$N = \frac{I\ (A+B+C+1/H)+Y}{s\ (1+t)}$$

$$(7)\quad I = \frac{Ns\ (1+t)-Y}{A+B+C+1/H}$$

$$(8)\quad V = Ns\ (1+t)-Y-I\ (A+B+C+1/H)$$

$$(9)\quad H = \frac{I}{(Ns\ (1+t)-Y-I\ (A+B+C)}$$

Certain General Principles.

Before a set of fixtures can be designed the dimensions of the article to be manufactured must be determined. This means that clearances and allowances must be made on certain dimensions for running, sliding, or driving fits. Furthermore, the tolerances must be established. In general the smaller the tolerances the greater the cost of production. The closeness of the tolerances governs the design and workmanship of the jig or fixture quite as much as the required rate of production.

When the drawings of the article to be manufactured have been checked and approved, a model should be made to within the tolerances given on the drawings. The model and drawings can then be used as the basis for design of the jigs and fixtures.

In tooling up for the manufacture of a piece, an operation sheet should be prepared, which includes every operation on the piece, both of production and of inspection or gauging, showing them in a single list in the order of their application.

The fixtures should be tied in with the system of gauging. The same points or surfaces should be used for locating the work in the fixtures and for reference points in the gauges. Only by so doing are the gauges a direct check on the fixtures. The same working points should be used on the two parts which go together in the manufactured output.

It is most important that, once settled upon, the same working or locating points be used for as many operations and gaugings as possible. Preferably they should be permanent and remain in the piece when finished. It is tempting at times to shift the locating point, as the fixture and gauge might then be made more cheaply, but to do so is poor practice, and, in the long run, poor economy.

If a multiple fixture is to be used of either the reciprocating or indexing type, the question of the time required for removing and inserting pieces is of fundamental importance, as the clamping means must be so designed that the pieces can be handled in the time taken for the cut.

In general, it is desirable to machine as many surfaces, or drill as many holes, as possible at one setting. This makes for accuracy, lessens tool expense, and cheapens

production, but is subject to some limitations as, for instance, the combination of a very large and very small hole in the same jig.

How far it is desirable to make a fixture adaptable to various pieces and operations is a matter of judgment in each case. It usually does not pay except where the runs are very small. In general, specialization is better than adaptability because the latter, while it lessens tool expense, permits errors in settings and "monkeying" with the set-up, Fixtures should be interchangeable on the various machine tools on which they can be used.

All jigs and fixtures should be clearly marked, preferably by stamping into the body where it can be done, the operation, part number, etc., for which it is intended, and any other information needed to identify it.

Despite the wide variety in jigs and fixtures many details may be standardized, such as bushings, latches, handles, thumbscrews, etc. A jig or fixture should:

(1) Locate the work quickly and positively.

(2) Preclude insertion of the work in any but the position correct for cutting.

(3) Provide rapid and positive clamping without undue effort.

(4) Allow no spring in the work, fixture, or machine table from either clamping or the pressure of the cutting tools.

(5) Allow no slipping, vibration, or chatter during the cut.

(6) Have ample clearance for chips, and be easily cleaned.

(7) Be as light as is consistent with strength and rigidity.

(8) Be safe for the operator.

TURBINE FOR ENGINE COOLING*

By Dipl. ING. B. KLOMPUS. (From *Flugtechnik/Technique Aeronautique*, Vol. 2, No. 9, September, 1940, pp. 207-10).

THE greater part of the energy content of the fuel supplied to I.C. engines is dissipated in various heat losses. In the following a method will be described how a part of these losses could be recovered, with special reference to aircraft engines.

Considering the definition of entropy, it is obvious that heat losses are present whenever there is a gain in the entropy during any part of the cycle on which the engine operates. A reversible cycle, such as the Carnot cycle, is not accompanied with heat losses, all practical cycles existing, however, deviate considerably from the reversible cycle. For a more practical point of view the following losses can be distinguished during the operation of an I.C. engine.

(a) Heat transferred to the surrounding air, either directly or by means of a cooling liquid.

(b) Heat losses in the heat content of the exhaust gases, and energy losses in the Kinetic Energy of the exhaust gases leaving the engine at high speeds.

For the purpose of our investigation we will consider an actual engine, similar to which have been already constructed. The particulars of the engine are as follows: Power 2000 H.P., " H " type, i.e. four cylinder blocks each of six cylinders. Output 40 h.p. per litre, giving a stroke volume of 50 l., speed 2500 r.p.m.

The engine is provided with two turbines: an exhaust-gas turbine and a steam turbine. The steam to drive the latter is generated by cooling the engine and by the heat content of the hot exhaust gases. A common blower

*EDITORIAL COMMENT.—The article does not take into account the fact that owing to the low pressure and, therefore, low temperature at which the steam is condensed, the temperature difference between the water in the radiator and the cooling fluid is much less than in the normal cooling system. Thus, with the condenser pressure of 0.06 atms. suggested in the article, the temperature of condensation is only 38° C. With cooling fluid at 15° C. the temperature difference across the radiator is only 23° C., as against, say, 90—15 = 75° C. for a normal system (without pressure cooling). Thus the size and weight of the cooler will be trebled, as will also the work needed to circulate the cooling fluid. Where the cooling fluid is air, as in the aircraft application proposed, this drawback would far outweigh the gains; where, however, ample cooling water is available, as in marine work, the cooling work is, in any case, small, and the above drawback does not apply.

is driven by the two turbines. (See Fig. 1). If the same turbine is fed by two or more motors care must be taken not to put the two units too far from each other, since this would make the plant too heavy. It is advisable to provide a separate turbine plant for each wing of a multi-engine aircraft.

The Steam Boiler on the Cylinder Head.

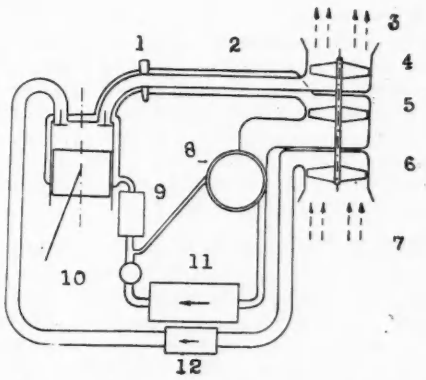
In contrast to ordinary engine designs the water jacket surrounding the cylinder should be designed so as to prevent radiating heat losses as far as possible, and further, the cooling water in the jackets is kept under a pressure. Practice only will show whether horizontal or vertical type of cylinders give more satisfactory results. A free circulation of steam in the jackets is most essential, and formation of steam pockets above the cylinder head must be carefully avoided. A new feature in the design is that a portion of the exhaust pipes is passing round the water jackets, in order to utilize the heat content of the exhaust gases for generation of steam, super-heating and cooling of the exhaust gases at the same time.

To calculate the quantity of steam produced a steam pressure of 3 atm. is assumed. This corresponds with a boiling point of 132.9° C., and a latent heat of evaporation of 518 kcal/kg. This boiling point temperature is well within the allowable limit considering the operation of the engine. The feed water is preheated to 100° C. The heat dissipated from the engine and available for steam generation is given by:

$$Q = e.P$$

where Q is the quantity of heat in kcal/sec., e is the specific heat-blow coefficient as given by the engine manufacturers, usually between 0.08 and 0.1 in kcal/sec. h.p., and P is the engine output in horse-power.

In the case of the example $Q = 0.088.2000 = 176$ kcal/sec., or 645,000 kcal/hour. Allowing 5% for heat losses, the total available heat (from engine cooling) is 612,750 kcal/hour. From the previous, 1 kg. of feed water requires 551 kcal of heat for the conversion to steam at the same temperature and pressure. Hence the boiler is able to produce 1100 kg. of steam per hour.



1 Separator, 2 Superheater, 3 Flue gases, 4 Exhaust gas turbine, 5 Turbine for Cooling, 6 Air inlet, 7 Air, 8 Centrifugal condenser, 9 Preheater, 10 Feed Pump, 11 Cooler, 12 Cooler.

Fig. 1.

Superheating and Steam Generation from the Heat of the Hot Exhaust Gases.

The advantages of superheating are:— greater adiabatic heat drop, improved turbine operation in the dry steam region, and lower exhaust gas temperature, hence improvement in the operation of the exhaust-gas turbine.

For cooling of the exhaust gases the exhaust pipes are surrounded by water jackets at the junction to the cylinder blocks, and the pipes are provided with concentric tubes in which the water circulates.

The exhaust gases leave the engine at approximately 1050 C., and have a mean specific heat of 0.26 kcal/kg.°. The quantity of the exhaust gases is easy to calculate and was found, in the case of the example, to be 4550 kg/hour. Hence the quantity of heat subtracted from the gases while cooled down to 550 C. is $0.26.4550.500 = 590{,}000$ kcal/hour. Again allowing for losses by radiation, etc., we are left with 570,000 kcal/hour available for superheating and steam generation. Since the steam is superheated to 550 C., this requires 221,000 kcal/hour, the remaining heat is used for the generation of additional 465 kg of superheated steam per hour. Thus the total quantity of steam available for the steam turbine is 1565 kg/hour.

Condensator.

Surface condensers cannot be employed, since there is no separate cooling water. A centrifugal pump is used instead for condenser, in which the exhaust steam is mixed with the cooling water. The hot water now enters a cooler, from which a part is conveyed to the feed pump, and the remainder returns to the pump (Fig. 1).

Leading Dimensions of the Turbine.

These are determined in the usual way, a Laval turbine being selected for this purpose with a maximum circumferential speed of 450 m/sec. The adiabatic heat drop can easily be determined from the Mollier chart, and is, in the case of the example, 240 kcal/kg, when a condenser pressure of 0.06 atm. is assumed. The consumption of a suitable turbine will be 4.13 kg/h.p. hour, and the output of the turbine thus becomes 380 h.p., or 19% of the engine power.

If the degree of superheat of the steam were only 150° C., conditions otherwise being identical with the previous case, the adiabatic heat drop would only amount to 140 kcal/kg., but the quantity of steam generated would be, in this case, 2120 kg/hour. The steam consumption of a turbine working under such conditions would become 6.6 kg/hour, and hence the output of the turbine would only be 321 h.p. or 16.8% of the engine power. It can thus be seen that for higher efficiency a higher degree of superheat is required.

Loading of the Turbine Blading.

The DVL 225a alloy has endurance figure for 1% elongation in 300 hours at 600° C. = 42-45 kg/mm². The endurance figure for P 193 alloy is 38 kg/mm². Allowing a safety factor of 2, which is advisable, the required endurance figure of a turbine working with an adiabatic heat drop of 180 kcal/kg and rotating at a maximum circumferential speed of 450 m/sec. is 16.6 kg/mm², which is well within the allowable limit.

Dimensions of the Condensor.

After estimating the leading dimensions of the turbine, the quality of the exhaust steam, and hence the quantity of cooling water required can be determined. With an adiabatic heat drop of 180 kcal/kg and 3 atm. steam pressure and 0.06 back pressure, 15% reduction in the quantity of cooling water is obtained compared with the case of an ordinary I. C. engine. By reducing the quality of the exhaust steam further improvement is obtained.

Turbines for 140 to 240 kcal/kg Adiabatic Heat Drop.

	Adiabatic Heat Drop					
	140	**160**	**180**	**200**	**220**	**240**
Degree of Superheat (steam pr. = 3 atm., back pr. = 0.08 atm.)	204	309	392	463	536	—
Ditto (back pr. = 0.06 atm.)	150	267	357	428	498	565
Ditto (back pr. = 0.04 atm.)	—	203	303	381	452	516
Quantity of steam in kg/BHP. hour	6.6	5.85	5.27	4.81	4.5	4.13
Output (eng. cooling used only for steam generation) in H.P.	167	188	209	228	245	263
Quantity of steam when exh. gases also used for steam generation. Exh. gases cooled to 550°C. (kg/h.)	2110	1920	1810	1700	1640	1570
Output in H.P., when exh. gases used for steam generation and superheating	323	330	341	353	365	380
Length of blading in cm. for steam pr. = 3 atm., back pr. = 0.06 atm., and max. circumf. vel. = 450 m/sec.	2.27	2.26	2.25	2.24	2.12	2.08

DISCUSSION.

In Fig. 2 the output of the turbine is plotted against the circumferential velocity of the runner, for various adiabatic heat drops. Group I. represents the case where the total heat of the exhaust gas is utilized for steam generation, Group II. represents the case where the heat content of the exhaust gas is only used for superheating. It can be seen that the variation of the adiabatic heat drop has less effect on the output of the turbines in case I. than in case II. The maximum permissible speed of the runner is about 300 to 450 m/sec.

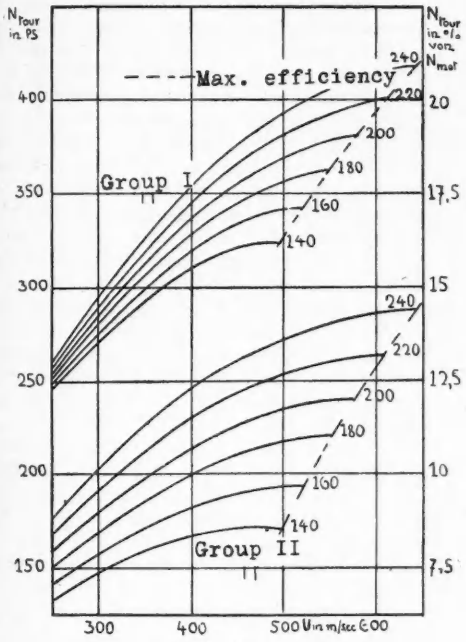


Fig. 2.

Fig. 3 shows the variation of the adiabatic heat drop with steam chest pressure, condenser pressure, and degree of superheat. The upper limit of superheating the steam is fixed by the heat resistance of the blading alloy.

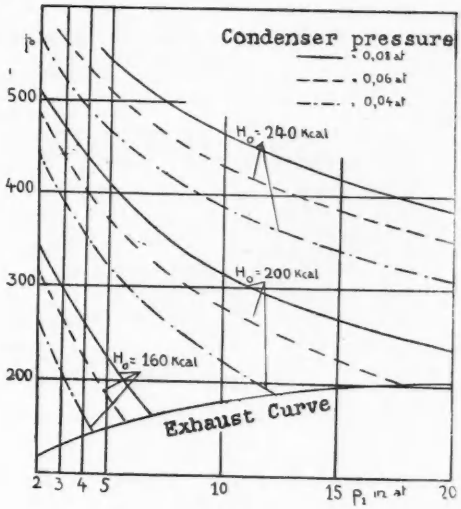


Fig. 3

The total weight of the turbine plant is a very important factor. However, it can be assumed that the increase in the weight of the cylinder due to the jacket is small, and the weight of the pipes can also be kept at a low value. The estimated weight of the turbine in the example is about 160 kg., i.e. 0.6 to 0.8 kg/h.p.

The weight of the exhaust gas turbine would be about 40 kg.

The last part of the article deals with the exhaust gas turbine, and gives some suggestions how the power saved by the turbines could be best utilized.

CENTRAL HEATING BOILER FOR WOOD FIRING

By Prof. Dr. P. Schlapfer and Dr. O. Stadler. (From *Schweizerische Bauzeitung*, Vol. 116, No. 21, pp. 242-243).

The quantity of air required for the combustion of dry wood is only half of that required for the combustion of coke. Reducing the grate area of the boiler is, however, not sufficient to ensure an efficient burning of the fuel. The wood storage in such a boiler would soon be heated up to a temperature causing elimination of gases. The air supply present is not sufficient to prevent this, and as a result smoke would develop and steam would condense. Charging of the boiler with wood fuel always causes abrupt fluctuation of the output and of the flow temperature. Therefore, throttling of the air should take place when the wood is freed from gases and not after charging the boiler.

The thermostatic controls used for coke-boilers do not give satisfactory results when the fuel is wood, since they are controlled by the flow temperature and would close the air supply when a large quantity of air is required for the combustion of the gases. The formation of condensed water is caused by the high dew point temperature of the flue gases which is about 30 to 60° C. In case of dry coke it is only 0° C.

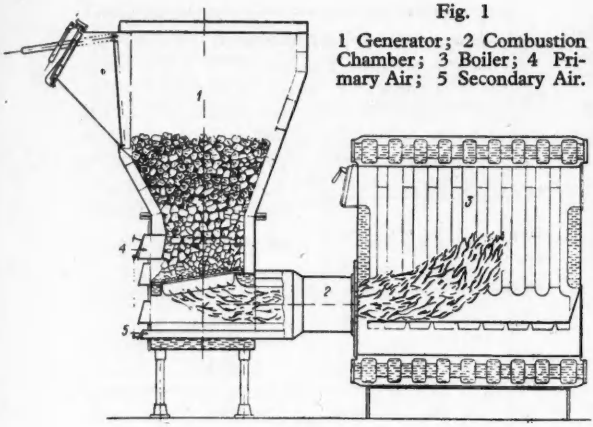


Fig. 1
1 Generator; 2 Combustion Chamber; 3 Boiler; 4 Primary Air; 5 Secondary Air.

In order to overcome these difficulties it is essential to provide three compartments for the following three processes :

(1) Carbonisation of wood.
(2) Combustion of the gases.
(3) Heat transmission of the gases to the boiler heating surface.

The third of these can take place in a cast-iron boiler, the first in a generator fitted in front of the boiler. For the second process a combustion chamber should be provided between the generator and the boiler (see Fig. 1). The primary air causes the wood to burn above the grate so that there is a continuous combustion of wood. This combustion can be controlled by a thermostat. In the combustion chamber the gases are mixed with pre-heated air. The gases are not cooled here. The hot flue gases are passing through the boiler, thus transmitting the heat. Such an installation has a fairly high efficiency of about 80% for the rating between the limits 1 to 5. A good insulation of the generator and the combustion chamber is essential.

The so-called " Schwedenkessel " (Fig. 2) has a slightly lower efficiency, but takes up much less room. The combustion chamber of the boiler is used as fuel bunker. The primary air is entering below the grate and leaves the boiler after mixing with the gases by passing through the grate a second time. Therefore, only the lower wood layer is burning, ensuring a steady running. Combustion proceeds in the second flue by mixing with secondary air, and the gases are escaping through the boiler flues. The efficiency curve for this boiler shows a very favourable shape and reaches a maximum of about 73% for an average rating.

Another possibility of burning wood is offered by a boiler plant fitted with a bunker. In a similar way as before, the wood is carbonized, freed from gases, and drops then as charcoal on the comparatively small grate. Pre-heated secondary air is introduced into the upper part of the combustion chamber. This type of boiler ensures a regular running and thermostatic controls can be used. The efficiency of such a plant would be about 60% and the characteristic is slightly rising with increasing rating. The shape of the bunker is to be adopted to the commercial size of wood.

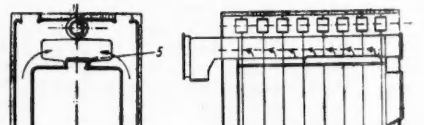


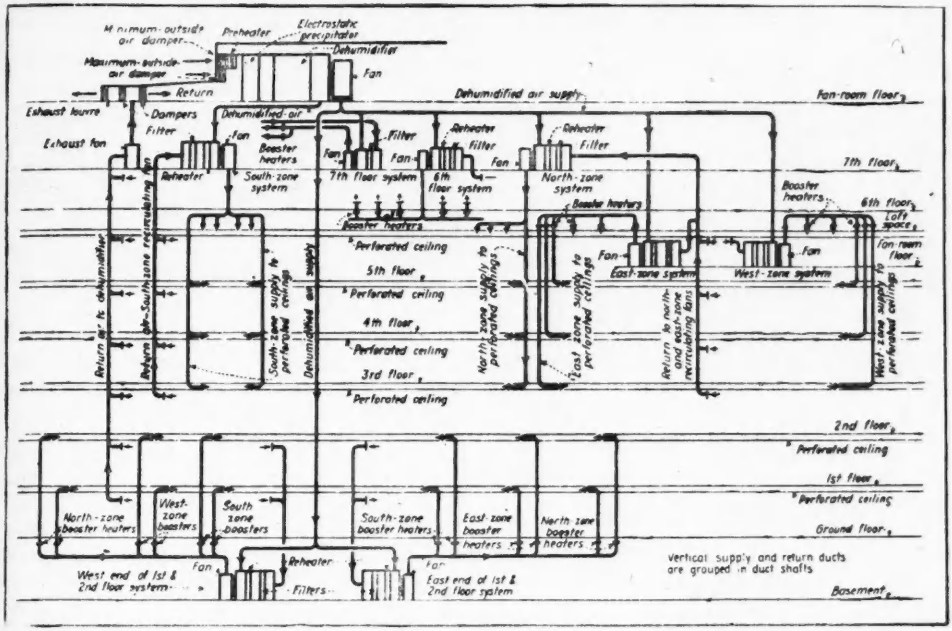
Fig. 2
1 Admission of Air; 2 Air Passage; 3 Flue; 4 Flue Gas; 5 Flue Damper.

AIR CONDITIONING PLANT for BANKER'S LIFE INSURANCE Co., DES MOINES, IOWA, U.S.A.

(From *Power*, Vol. 84, No. 10, October, 1940, pp. 93-95).

THE office of the Banker's Life Insurance Co. is thought to be the largest commercial building recently erected in the U.S.A. with private capital.

Although the air-conditioning system can heat the building independently, partial panel heating, or wall warming, eliminates cold draughts close to wall and glass surfaces and



reduces radiation from the body to these normally colder areas. This supplementary heating makes it possible to utilize floor space up to the walls.

Continuous bare copper pipes, 1 in. diameter, running along the walls and around the windows fit in the space between corkboard insulation and enamelled-steel finishing plates. These pipes carry hot water in winter, raising wall temperature sufficiently to produce a combined wall and window radiating temperature approximately 70° F. In winter the pipes carry cold water. During winter months the wall-warming pipes will keep the building at reasonable temperature when unoccupied, reducing the time required for bringing the system to operating conditions in considerably less than one hour.

Supply and return air is distributed through the building, in the main, by vertical utility shafts. Fresh air from pre-heater mixes with part of the return air before entering a 124,000 C.F.M., 180-cell, electrostatic precipitator, installed to remove smoke particles which would pass through conventional filter. An air washer adds or removes moisture as needed and also takes care of summer cooling.

Conditioned air flows to a main supply fan which serves seven local recirculating units, supplying various building zones.

The basic control set up for the working floors divides them into four zones according to the points of the compass, with separate supplies for each. Wall warming piping is similarly divided.

In each zone, thermostatic control regulates temperature and humidity of supply air and temperature of water in wall piping, thus allowing for variations in sun exposure and wind direction.

Three 15 × 10 in. vertical, single acting, Freon-12 compressors produce 650 tons of refrigeration for cooling. Capacity controls and compressor cylinders permit reduction of output in 4 steps to $87\frac{1}{2}$, 75, $62\frac{1}{2}$ and 50 per cent of rating.

Three automatic oil fired boilers supply hot water for wall warming and for general building service. An operating panel shows pressure, overfire draught, and smoke density. A separate panel carries CO_2 recorders.

Operation of the air-conditioning and other building services is centralized in the engine room at a control desk and switchboard.

TRAIN PROTECTION DEVICE with AUTOMATIC AXLE COUNTER

By ING. R. ZAUGG. (From *Schweizerische Bauzeitung*, Vol. 116, No. 23, 7th Dec., 1940, pp. 259-264).

RECENT improvements of axle counting apparatus have resulted in a wider application of this system for train protection. The principal idea of this device is to count automatically the number of train axles entering a particular section of the track, and counting them again when the train is leaving at another section. If the number of train axles entering and leaving the track are the same, the track can be considered to be free from trains between the two sections. It is not essential to count the actual number of axles : it is sufficient to register the entering and leaving axles in a comparable form.

The first practical application of this system was adopted in the new Hauenstein-Basis tunnel along a 10-km. block. The constant manual supervision of the line in the tunnel was eliminated by an axle-counting apparatus by adopting a mechanically-operated pedal-contact maker. According to the conditions of the wheel rim (new or worn) the pedal is pressed down by the wheels by about 3 to 10 mm., thus closing a circuit. The effective length of the pedal is 25 cm. The time of operation of the current impulses at a train speed of 100 km./h is about 1/100 sec. To count two axles 1 m. apart, sufficient time must elapse to allow the pedal to return to the neutral position between the two wheels. Hence, the pedal should return in about 1/50th of a second. For this, a spring pressure of 80 kg. will be sufficient, and this will also prevent faulty operation of the pedal due to people stepping on it.

With increasing traffic and train speeds, however, the pedal contact becomes unreliable. As many as 150,000 operations per month would be required from the pedal. Consequently some of the instruments were replaced by inductive counting devices, developed by Messrs. A. G. Signum. The principle of this device is shown in Fig. 1. On a permanent magnet NS there are two laminated iron poles

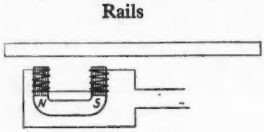


Fig. 1

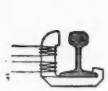


Fig. 2

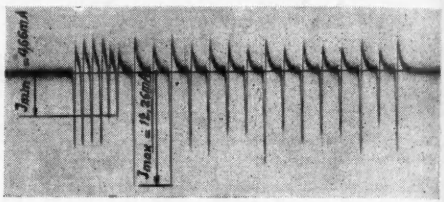


Fig. 3.

pointing towards the track. As a wheel approaches the track section, an increase in the magnetic field is produced and hence a current is set up. As the wheel leaves the point on the rail opposite the magnet, a current is again set up, but in the opposite direction. This second current is of smaller value than the first one, especially if the train speed is high. The oscillogram (Fig. 3) is a typical record of the current impulses set up by a train moving at 75 km/h.

In order to obtain uniform current impulses at higher speeds, two magnets are used, connected in series.

The receiving set consists of a very sensitive instanteneous relay, controlling the current for the actual registering apparatus.

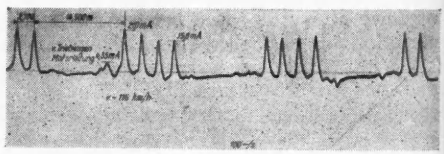


Fig. 4.

Another design is shown in Fig. 2 and consists of an electro-magnet with laminated iron cores in metallic contact with the track. With this arrangement the induced currents are much greater. A typical oscillogram obtained with this device is shown in Fig. 4.

The Author describes in detail the modifications required for particular conditions, such as train speeds below 5 km/h, and for trains manœuvring at both ends of a rail section.

In the rest of the article a few applications of this system are quoted.